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EFFECTS OF SOME ENVIRONMENTAL FACTORS ON WEANLING TRAITS OF RANGE RAMBOUILLET LAMBS

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BOTH induced and natural environmental factors operate to conceal genetic merit, thereby confusing the breeder and obstructing his efforts to select those animals having the greatest breeding value. In many instances variations in environment can be eliminated or controlled, but in others only adjustment or correction is capable of placing animals on a comparable basis. For example, two animals which have equal breeding value may differ widely in phenotype because of a difference in time of birth with attendant more or less favorable conditions of development, age of dams, twinning, etc.

Donald and McLean (1935) studied the factors which influence the growth rate of purebred and cross-bred lambs of mutton breeds in New Zealand. Their findings indicated that generally ram lambs, single lambs and lambs from mature ewes were superior in growth rate to ewe lambs, twin lambs and lambs from 2-year-old ewes, respectively. Phillips and Dawson (1937, 1940) found that the selection of Hampshire, Shropshire and Southdown lambs under farm conditions in the Eastern United States was affected by type and time of birth and birth weight of lambs. Bonsma (1939) found that sex and number of parturition affected growth and development of Merino and cross-bred lambs in South Africa.

The purpose of the present study was to ascertain the importance of several environmental sources of variation as they affect the weanling traits of Rambouillet lambs under Intermountain range conditions of the western United States. The factors studied were sex, age of dam, year, breeding group, type of birth, age at weaning and amount of inbreeding, and the weanling traits were body weight, staple length, body type, condition, face covering and neck folds.

Description of Data

The data used in this study were taken on 2183 Rambouillet lambs as a routine part of the breeding program of the Western Sheep Breeding Laboratory, Dubois, Idaho. The aim of the program is to improve the wool and meat production of range sheep. The lambs were born in April and May of 1941 and 1942, herded with their dams on sagebrush-grass range near Dubois,

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Idaho, until about July 1, when they were trailed with their dams to the high summer range in the Targhee National Forest. They remained on summer range until weaning time in the latter part of August. This system of management is typical of that under which sheep are handled in the Intermountain range districts of the Western States and for this reason is an essential part of the program. Under this system, however, many uncontrolled factors quite apart from genetic merit may influence performance and appearance.

The weanling records were taken by experienced animal husbandmen at or near weaning time. A committee of two or three men working independently scored body type and neck folds. A second committee scored face covering and measured staple length at the middle of the side to the nearest 0.2 cm. An additional man scored the lambs for condition, or degree of fatness. Weaning weights were taken by still another man to the nearest pound. The scoring system was the same for the four traits evaluated by scoring; lambs considered as having the highest merit were given a score of 1 and those of poorest merit a score of 5. Fifteen scoring units were obtained by assigning plus or minus values to lambs having scores slightly above or below the whole unit. The scores given by the two or three judges were averaged and rounded off to the nearest scoring unit of $\frac{1}{3}$. For example, two animals with scores of 3, 3 and 3+ and 3, 3 and 3−, respectively, would each have been assigned scores of 3.00 as their final weaning records.

Method of Analysis

The numbers of lambs weaned are listed in table 1 according to their various classifications. Because of the very unequal class numbers, Yates' (1934) method of fitting constants was employed in analyzing the data. This method was designed for the application of analysis of variance to data where multiple classification with unequal numbers in the different classes is encountered. Two constants were fitted for sex (males and females), groups (A and B), years (1941 and 1942), and age of dam (mature and 2-year-old ewes), while three were fitted for type of birth and rearing (singles, twins raised together, and twins raised singly). The lambs in groups A and B were produced by different mating systems, varied somewhat in average age and inbreeding, and were grazed on different ranges.

The procedure of fitting the 11 constants was carried out separately for each of the 6 traits, for age at weaning, and for percent inbreeding. The lambs in the various classifications differed significantly in age at weaning and in percent inbreeding; consequently adjustments were made in the 11 constants for each of the 6 traits, using multiple covariance technique with age at weaning and percent inbreeding as independent variables.

An analysis of variance table was then constructed for each trait. The variance due to the direct effects of each source of variation was calculated with the remaining six held constant as outlined by Yates. The sum of the variances due to the direct and combined effects of the 7 sources was designated as that due to main classes. This sum was subtracted from the total variance to obtain the variance within main classes. This procedure was convenient for making tests of significance and for estimating the quantita-

TABLE 1. NUMBERS OF LAMBS WEANED, GROUPED ACCORDING TO BREEDING, SEX, TYPE OF BIRTH AND REARING, YEAR AND AGE OF DAM

Group	Sex	Type of birth and rearing	1941		1942	
			Mature ewes	2-yr-old ewes	Mature ewes	2-yr-old ewes
A	Males	Singles	155	29	190	53
		Twins raised singly	48	0	55	3
		Twins raised together	92	0	107	0
	Females	Singles	177	39	192	62
		Twins raised singly	54	0	73	7
		Twins raised together	105	0	162	4
B	Females	Singles	105	95	115	89
		Twins raised singly	31	2	17	0
		Twins raised together	71	1	46	2

tive importance of the variation associated with the different factors. It was possible at this stage to test an assumption made at the beginning of the analysis; namely, that the effects of the different factors were additive. For example, if rams differ from the average by a, and single lambs by b, then single rams are assumed to differ by $a+b$. The interactions between the different factors were either nonsignificant or small as compared with the variation within classes for each of the six traits; hence it was concluded that the additive assumption was justified.

Experimental Results

The pertinent data concerning variations in the traits are summarized in tables 2, 3 and 4. The mean, standard deviation within classes, differences in main effects and the regressions on age at weaning and percent inbreeding for each trait are shown in table 2. The differences in main effects were calculated from the 11 constants fitted for each trait. For example, with weaning weight, the constant for rams was $+4.15$ and that for ewes was -4.15;

TABLE 2. MEAN, STANDARD DEVIATION, DIFFERENCES IN MAIN EFFECTS, AND REGRESSION COEFFICIENTS FOR EACH OF THE SIX TRAITS AT AN AVERAGE AGE OF 124 DAYS

Statistic	Weaning weight	Staple length	Body type	Condition	Face covering	Neck folds
	pounds	centimeters	score	score	score	score
Mean	69.0	2.66	2.55	2.27	4.28	1.75
Standard deviation	8.48	0.46	0.48	0.43	0.61	0.77
Ram minus ewe	8.3*	−0.48*	−0.43*	0.06	0.26*	0.11
Mature minus 2-year-old ewe	6.1*	0.19	0.16	−0.16	0.08	0.25
1942 minus 1941	0.2	−0.08	0.05	0.06	−0.14	−0.28*
Group A minus group B	0.9	0.12	0.06	−0.01	0.03	−0.18
Single minus twin	9.2*	0.05	−0.23*	−0.25*	−0.05	0.37*
Single minus twin raised singly	2.5*	0.13	−0.10	−0.09	0.02	0.07
Regression on age at weaning	0.413*	0.012*	−0.012*	−0.009	−0.002	0.010
Regression on percent inbreeding	−0.375*	−0.003	0.011*	0.009*	0.006	−0.009

* Signifies that the statistic is large enough to account for 2 percent or more of the total variation.

TABLE 3. SUMMARY OF ANALYSIS OF VARIANCE FOR EACH OF SIX TRAITS

(Mean squares only)

Source of variation	Degrees of freedom	Weaning weight	Staple length	Body type	Condition	Face covering	Neck folds
Total	2182	141.7	0.26	0.27	0.21	0.39	0.74
Main classes	8	19,117.3	12.70	11.20	6.03	5.99	21.09
Sex	1	27,599.4**	62.56**	47.90**	1.64**	17.01**	3.12*
Age of dam	1	9,724.0**	8.92**	7.49**	7.24**	1.65*	9.58**
Year	1	23.5	3.73**	1.99**	0.02	10.11**	39.25**
Group	1	105.7	3.65**	1.12*	0.00	0.13	4.00*
Type of birth	2	18,874.7**	1.54**	9.73**	11.29**	0.56	25.37**
Age at weaning	1	15,699.5**	12.48**	12.35**	6.83**	0.33	10.01**
Percent inbreeding	1	19,872.2**	1.15*	17.55**	11.15**	5.49**	12.27**
Within main classes	2174	71.9	0.21	0.23	0.19	0.37	0.67

* Signifies probability of chance occurrence <.05.
** Signifies probability of chance occurrence <.01.

hence the difference, rams minus ewes, was 8.3 pounds. Table 3 gives the analysis of variance and tests of significance for the different sources of variation. The practical importance of the 7 sources is shown more clearly in table 4 where the variation attributed to each source is given as a percentage of the total variation.

Weaning Weight

Rams were 8.3 pounds heavier than ewes, and single lambs were 9.2 pounds heavier than twin lambs (table 2). These figures are in the same direction and appear to be of approximately the same relative magnitude as those reported by Donald and McLean (1935) and Phillips and Dawson (1940) although the ages are not exactly comparable. The difference of 2.5 pounds between singles and twins raised singly shows that twinning is slightly detrimental to subsequent growth, even when post-natal conditions are otherwise similar. This may be due to the smaller birth weight of twins,

TABLE 4. PERCENTAGE OF TOTAL VARIANCE ATTRIBUTED TO EACH MAIN SOURCE OF VARIATION

Source of variation	Weaning weight	Staple length	Body type	Condition	Face covering	Neck folds
Sex	8.9	11.1	8.2	0.4	2.0	0.2
Age of dam	3.1	1.6	1.3	1.6	0.2	0.6
Year	0.0	0.6	0.3	0.0	1.1	2.4
Group	0.0	0.6	0.2	0.0	0.0	0.2
Type of birth	12.2	0.5	3.3	4.9	0.0	3.2
Age at weaning	5.1	2.2	2.1	1.5	0.0	0.6
Percent inbreeding	6.4	0.2	3.0	2.4	0.6	0.8
Within main classes	50.5	81.9	84.7	89.5	94.4	89.6

as Phillips and Dawson (1940) and others have found a significant relationship between birth weight and subsequent growth rate. Lambs from mature ewes weighed 6.1 pounds more than lambs from 2-year-old ewes, a difference similar to that found by Donald and McLean (1935) in New Zealand. The effects of sex, age of dam, and type of birth and rearing on weaning weight were highly significant (table 3). They accounted for 8.9, 3.1 and 12.2 percent, respectively, of the total variation in weaning weight (table 4). Differences between years and between groups were not large enough to be significant.

The regression of weaning weight on age at weaning shows that the lambs were gaining at an average rate of more than 0.4 pounds per day at weaning age. This is higher than the figures indicated in studies by Phillips and Brier (1940) and Phillips, Stoehr, and Brier (1940) on the growth rates of

lambs of similar age. The average weight of the present lambs, 69 pounds at 124 days of age, was somewhat heavier than those of the other studies, so that a higher rate of gain per day may be expected. The regression of weaning weight on percent inbreeding (−0.375 pound) indicates that inbreeding has a very detrimental effect on weaning weight. This reflects the combined effects of inbreeding in both the dam and the offspring, since the more highly inbred ewes generally had lambs with greater than average inbreeding. The effects of both age at weaning and percent inbreeding are sufficiently pronounced to require adjustment when differences in these factors are very great.

Length of Staple

Ewe lambs averaged 0.48 cm. more in staple length than ram lambs. The causes of this difference, the period at which it originates, and the length of time it persists, are unknown. Since studies of additional data show a similar sex difference in other years, it is not a peculiarity of the data in 1941 and 1942 alone. All of the sources except percent inbreeding had highly significant effects upon staple length (table 3) but only the difference between sexes, and possibly that between ages of dams, was sufficiently large to warrant adjustment (table 4).

Length of staple must increase at an average rate of about 0.02 cm. per day from birth to weaning in order to attain the observed average length of 2.66 cm. at 124 days of age. The regression of staple length on age at weaning indicates that the average difference in staple length was only 0.012 cm. for each day of difference in age. The observed coefficient of 0.012 is significantly smaller than a theoretical coefficient of 0.02; hence sampling error is unlikely to be the sole cause of the difference. The observed regression is influenced by any effect which time of birth might have upon subsequent growth in staple, as well as by differences in age at weaning. The discrepancy may be explained by a more rapid increase in length of staple among late-born lambs than among those born early, but this situation cannot be clarified from the data at hand. However that may be, differences in staple length due to age are important enough to require adjustment (table 4) when age differences are at all large. Percent inbreeding has so little influence upon length of staple that it may be regarded as an unimportant source of error.

Body Type

Ram lambs were scored 0.43 point poorer in type than ewe lambs. This difference may have resulted from a higher standard for ram lambs because of the more stringent selection which is practiced for rams than for ewes. The ewe lambs and ram lambs were scored for body type on different days in

both 1941 and 1942. More recently, all lambs have been scored at random with regard to sex, and preliminary analyses of these data show that the sex difference is much reduced when body type is scored in this manner. Although the sex difference is an important source of variation in type score in the present data (table 4), it is probably not typical of the difference expected under other conditions. Subjective scores, which depend upon mental standards, such as those given for body type, are subject to change from time to time or from man to man and are unlikely to be strictly comparable over a period of time. Single lambs were given better type scores than twin lambs raised singly which in turn excelled twins raised as twins. Starke (1945) reported similar differences in conformation score between rams and ewes and between singles and twins in South Africa. Differences due to age of dam, year, and group were statistically significant but they accounted for only a small percent of the total variation (table 4) in these data.

Score for body type improved with age at weaning and became poorer with increased inbreeding as shown in table 2. These factors exerted sufficient influence upon scores for body type to be fairly important sources of variation.

Condition

Differences due to sex, age of dam, and type of birth were highly significant for condition, or degree of fatness. Scores for condition were given prior to separating the lambs by sexes, and this may account for the much smaller sex difference than that found for body type. Twins were scored 0.25 poorer than single lambs and this difference is large enough to require adjustment (table 4). With the possible exception of age of dam, the other differences are unimportant. The factors studied have about the same influence upon scores for condition as upon those for body type, except for sex.

Scores for condition improved with age at weaning and became poorer with increased inbreeding. These regressions are slightly smaller and are in the same direction as those for body type. Their effects may be important sources of error in comparing condition for lambs which differ considerably in age or in percent inbreeding (table 4).

Face Covering

The ram lambs were scored as having considerably more covered faces than ewe lambs (table 2). An earlier study (Terrill, 1941) and additional yearly averages for the two sexes indicate that the sex difference has been consistent over a considerable period. Preliminary studies indicate that the difference is much less marked in breeds having more open faces than Rambouillets. Lambs from 2-year-old ewes and those born in 1942 were more

open-faced than those from mature ewes and those born in 1941, respectively. These two differences may represent genetic changes due to the selection being practiced for more open-faced sheep. Although sex, age of dam and years were statistically significant, only the sex difference seems large enough to warrant adjustment.

Since the regression of face covering on age at weaning was not significant there is no evidence that face covering changes appreciably from 100 to 140 days of age. However, the yearling scores for the animals kept to yearling age indicated that both sexes were considerably more covered as yearlings than as lambs. Terrill (1941) also reported that ewes were more covered as yearlings than as lambs. The regression on percent inbreeding shows that the more inbred lambs had slightly more covered faces. The error involved is slight regardless of whether adjustment in face covering is made for inbreeding or not.

Neck Folds

The greater development of neck folds in ram lambs, single lambs and lambs from mature ewes than in ewe lambs, twin lambs and lambs from 2-year-old ewes suggests that the development of folds is strongly influenced by those factors which are favorable to growth in lambs. Carter (1941) found that the development of neck and body folds in Merinos was reduced on a low plane of nutrition and augmented on a high plane. The cause of the difference between years is less clear, but, since rather intense selection was being practiced for smoothness, it is to be expected that the lambs born in 1942 carried fewer of the genes which cause folds than those born a year earlier. It is also possible that a shift in the scoring standard for neck folds caused some of the difference. Although the variation attributed to each of the sources was statistically significant, only the difference between years and that between singles and twins were large enough to warrant adjustment (table 4).

The regression of neck folds on age at weaning is +0.01, indicating that the development of neck folds is not complete at weaning age. This continued development points to progressive increase in the size of folds already present or to the appearance of additional folds. While the regression coefficient is too small to account for much of the variation in the present data, the comparison of animals differing more widely in age, as with lambs and yearlings, may be biased considerably by age differences. From the small negative regression of neck folds on percent inbreeding, it seems that errors due to differences in inbreeding are not likely to be large.

Discussion, and Application of Results

Some of the traits were influenced much more by the environmental fac-

tors studied than were others. For example, the direct and combined effects of the 7 factors accounted for 49.5 percent of the total variation for weaning weight as compared with 5.6 percent of that for face covering. Consequently selection for open face would be impeded only slightly if the factors were disregarded, whereas the effectiveness of selecting for weaning weight would be reduced by about one-half.

Many other factors of less tangible or measurable character, such as parasitism, dams with spoiled udders, errors in scoring, etc., undoubtedly affect some of the traits. Their effects together with the hereditary variation are represented by the variation within classes. If the latter should be due largely to genetic variation according to the multiple factor scheme, then genetic progress from selection will be rapid. Conversely, improvement will be slow if environmental factors yet unstudied are responsible for a large proportion of the variation within classes, and if remedial control measures cannot be found.

Phillips and Dawson (1940) proposed three methods whereby differences due to sex, type of birth, and time of birth could be at least partly overcome in selecting breeding animals: (1) Separate the lambs into groups according to sex, type of birth, and time of birth; (2) make selections at a standard age, using adjustments for sex and birth factors; and (3) postpone selection until a later age when differences in development are more nearly equalized.

The advantages of one method may outweigh those of another with different breeders, depending upon their individual circumstances. Large range operators who do not keep detailed records may conveniently practice the first method by running early and late lambs, single and twin lambs, and lambs from mature and 2-year-old ewes in different bands and by making selections before the lambs from the different bands are mixed. This method has much to recommend it as good management practice also.

Breeders with smaller flocks and those who keep detailed records will probably find a combination of the second and third methods most satisfactory. The least work is involved by adjusting the smaller groups to the largest group. Thus 6.1 pounds and 9.2 pounds would be added to the weaning weights of lambs from 2-year-old ewes and twin lambs, respectively, to adjust weaning weight to a mature dam, single lamb basis. Since the factors are additive 15.3 pounds would be added to the weight of a twin lamb from a 2-year-old dam. Lambs differing considerably in age or inbreeding can be adjusted to a definite standard, usually the flock average. Thus in a flock averaging 125 days at weaning age and 5 percent inbreeding, a lamb 135 days old at weaning with 12 percent inbreeding would have 1.5 pounds deducted from his weaning weight $[0.413(135-125)-0.375(12-5)=-1.505]$. Phillips and Dawson (1940) found that the initial disadvantages of

twinning and later birth had largely disappeared by 1 year of age. Hence proper adjustment at weaning age may allow for the keeping of lambs where merit will have become manifest before a second culling is made. Constructive breeders generally allow for later culling by keeping more lambs than will actually be needed for replacements particularly where there is a market for yearling breeding stock.

Sex differences do not confuse selection among the lambs because both ram lambs and ewe lambs must be kept for replacements in their respective groups. However, progeny tests or the performance of other relatives can be evaluated more accurately, particularly where the number of lambs is small, if records are adjusted for differences in sex. For example, where ewes are credited for lamb production, the sex of the offspring has no significance so far as the breeding value of the dam is concerned, yet the sex difference in weaning weight or staple length is large enough to cause a good ewe to be culled or a poor one kept.

Summary

The effects of sex, age of dam, year, breeding group, type of birth, age at weaning and percent inbreeding were studied on 2183 range Rambouillet lambs born in 1941 and 1942. The average age at weaning was 123.8 ± 11.1 days.

Differences in weaning weight between ram lambs and ewe lambs, single lambs and twin lambs, and lambs from mature ewes and those from 2-year-old ewes were 8.3, 9.2, and 6.1 pounds, respectively. Ewe lambs, single lambs, and lambs from mature ewes had higher body type and condition scores than the contrasting groups. Ram lambs had more neck folds and more wool on their faces than ewe lambs. Weaning weight, staple length, and body type and condition scores improved with age at weaning and became poorer with increased inbreeding, as shown by regression coefficients.

The factors studied had the greatest influence on weaning weight and the least on face covering, accounting for 49.5 and 5.6 percent, respectively, of the variance in these traits. It is suggested that the more important differences be considered in culling lambs, thereby increasing the improvement expected from selection. This can be accomplished by sorting the lambs into groups according to sex, type of birth, age of dam, etc., or by adjusting weanling records. Progeny test comparisons, particularly with small numbers of offspring, can be made more accurately after adjusting for the important factors.

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SEXUAL DEVELOPMENT OF RANGE EWE LAMBS AS AFFECTED BY WINTER FEEDING

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THE first winter is perhaps the most critical time in the development of the range ewe. Up to weaning, the range lamb is provided with a reasonably adequate diet in most cases, while with its dam on spring and summer range. When weaned and moved to winter range, there is often a decided drop in the level and quality of nutrition, and this is accompanied by more severe environmental conditions in other respects.

Little is known of the effects of these conditions upon the sexual development and subsequent reproduction of ewes. The work described in this paper was designed to obtain information on this problem.

Previous Work

A comparison was made by Esplin, Madsen and Phillips (1940) of groups of ewe lambs maintained on open range and in feed lots during their first winter. All the lambs in feed lots received alfalfa hay and a mineral supplement, and, in addition, two groups received barley and corn silage, respectively. These trials were repeated in three consecutive years. Lot-fed lambs grew faster, had longer staple fleeces, and death losses were lower. The differences in lamb production between the lot- and range-fed groups at two years of age was rather striking.

Following the winter-feeding period, the lot-fed lambs were returned to the range herd in which the controls were maintained. By breeding time the following fall they had lost most of the weight advantage gained over the range-fed lambs during the winter period. However, the conception rate was higher than in the range-fed ewes. Of 207 lot-fed ewes in the herd at breeding time, 64.7 percent lambed, compared with 45.5 percent of 123 ewes in the range-fed groups. These percentages are averages based on three years' work and the difference was highly significant.

Many workers, including Marshall (1908), Marshall and Potts (1924), Nichols (1926) and Clark (1934), have reported increases in lamb crop or in ovulation rate as a result of providing a high level of nutrition just prior to and during the breeding season. The results reported by Esplin, Madsen

[1] This work was conducted at the Utah Agricultural Experiment Station. The authors are indebted to Dr. George Stewart and Selar S. Hutchings of the Intermountain Forest and Range Experiment Station, U. S. Forest Service, Ogden, Utah, for helpful cooperation in the phase of this work conducted at the Desert Range Station, near Milord, Utah.

and Phillips (1940) are in a different category, since the feeding ended approximately six months before the first breeding season, and the advantage gained by feeding, as measured by body weight, had nearly disappeared at breeding time. Thus, it appears that the lot-feeding of ewe lambs stimulated development of the reproductive tract, or development of some other type associated with reproduction, that carried over to the subsequent breeding season.

Experimental Animals and Procedures

Eighty ewe lambs were obtained from a range flock near Cedar City, Utah, in mid-October. They were divided into two comparable groups. One group was lot-fed at Cedar City on a ration of alfalfa hay, supplemented with bone meal and salt. The other group was placed on experimental winter range at the Intermountain Forest and Range Experiment Station's Desert Range Station, west of Milford, Utah.

The ewe lambs at Cedar City were checked for estrus each morning and evening with aproned teaser rams. Those at the Desert Range Station had aproned teasers with painted chests running with them. According to plan, half of the lambs coming in estrus in each group were to have been slaughtered about 36 hours after estrus began, to obtain data on the reproductive tracts. However, none of the lot-fed lambs exhibited estrus, and only two of the range-fed groups were marked. Neither of these had ovulated, when slaughtered 30 and 35 hours after the markings were observed, so it appeared probable that they were marked accidentally.

Half of the remaining ewe lambs in each group, selected by lot, were slaughtered at the end of January (January 29–31) to obtain data on their reproductive tracts. Including the two slaughtered somewhat earlier (one in late November and one in December) in the range group, 18 were slaughtered from the lot-fed group and 16 from the range-fed group. There had been some death losses from coyotes and other causes.

The remaining lambs in the lot-fed group were continued on feed and the range-fed group was kept on the experimental range pastures, until April of that year. Both groups were then placed in the range herd, from which they had been obtained, and maintained there for the summer. When the herd moved off summer range the following fall, all the remaining lambs, now yearlings, were taken to the Desert Range Station and placed on winter range. Rams with color-marked chests were run with them and after the breeding season the ewes that had survived to this time were slaughtered, and data obtained on the reproductive tracts. Successful breeding dates ranged from December 15 to January 1, and slaughter dates ranged from January 14 to January 25. In each case sufficient time for an estrous cycle had

elapsed before an animal was slaughtered, so there could be reasonable certainty that the animal was pregnant.

The observations made on reproductive tracts that appeared to be of critical value in determining the effect of lot-feeding are indicated in the next section.

Results

The data are summarized in table 1. The records obtained on ewe lambs during the first winter indicate that the tract was larger in the lot-fed group and that there was more ovarian activity, as measured by the number of large

TABLE 1. COMPARISON OF REPRODUCTIVE TRACTS OF EWE LAMBS, FOLLOWING EXPERIMENTAL RANGE- AND LOT-FED PERIODS

Item compared	Group		Difference between groups
	Range-fed lambs	Lot-fed lambs	
Records during first winter			
No. of lambs	16	18	—
Avg. length of reproductive tract (mm.)[1]	356.2	419.2	63.0[2]
Avg. no. of follicles 2 to 4 mm. in diameter	12.2	11.2	1.0
Avg. no. of follicles over 4 mm. in diameter	1.7	3.1	1.4[3]
Avg. diameter of follicles over 4 mm.	4.6	5.5	.9
Records during second winter			
No. of ewes	12	14	—
Avg. length of reproductive tract (mm.)[1]	222.4	251.1	28.7[4]
No. of pregnancies	9	12	—
Percent of ewes pregnant	75.0	87.5	12.5[5]

[1] The length of reproductive tract during the first year included vagina, cervix, uterine horns and fallopian tubes. During the second winter, only the vagina, cervix and uterine horns were included.

[2] Highly significant, $P = <.01$.

[3] A chi-square test of the proportion of total follicles over 4 mm. in diameter indicated that it was significantly higher ($P = <.01$) in the lot-fed group. The lot-fed animals were highly homogeneous in the proportion of large follicles ($P = .70$), while the range group were heterogeneous ($P = .01$).

[4] The means differed significantly, $P = .03$.

[5] The two groups did not differ significantly, as determined by the chi-square test.

follicles. These lot-fed lambs averaged 55 pounds in weight at the beginning of the feeding period and gained an average of 10.4 pounds up to the time of slaughter. The range-fed group weighed 59.1 pounds when put in the experimental fenced-range pastures, and gained 7.4 pounds.

The effect of feeding during the first winter appeared to carry over to the

following breeding season, as indicated by the larger reproductive tracts in the ewes that had been lot-fed as lambs. Also, a higher proportion of these ewes became pregnant. This difference in conception rates was not statistically significant, but it was in line with the results, obtained in three consecutive years, reported by Esplin, Madsen and Phillips (1940). Four out of 17 ewes carried on the range their first winter failed to show estrus during the succeeding fall breeding season as compared with one out of 16 ewes that received extra feed during their first winter. The ewes from the lot- and range-fed groups in the present study weighed 88.9 and 81 pounds, respectively, at the time of slaughter.

These results, along with those of Esplin, Madsen and Phillips (1940), indicate that the diet of the ewe lamb during the first winter is a critical factor in determining reproductive capacity during the following year. In addition to an increase in reproductive capacity, death losses are lower in lot-fed groups, hence more ewe lambs are available from which to select replacements in the breeding herd. Thus, the desirability of giving special attention to the ewe lambs during their first winter is indicated. Further work is needed to determine how far the rancher can afford to go in giving special attention to his ewe lambs. There are several possibilities, including favoring them with the best range, giving supplemental feed on the range, and lot feeding. Also, it is possible that some specific dietary factor (or factors) is deficient in the range forage in certain areas. If so, and if the specific factor or factors can be determined through suitable experimental work, then the problem of adequate supplemental feeding might be simplified. It is also possible that there is an especially critical period in the development of the reproductive tract of the ewe lamb when supplemental feeding might be most effective. Another phase of the problem that is important is the extent to which the apparent benefits of lot-feeding the ewe lambs may carry over beyond the first breeding. In the solution of the various details of this problem, there lie possibilities of great benefits to range sheepmen.

Summary

Results of a study of the effects of lot-feeding of range ewe lambs during their first winter indicate that the reproductive tract develops more fully, as compared with development in ewe lambs maintained on open range. These results, coupled with earlier work in which larger lamb crops were produced at two years of age as a result of lot-feeding during the first winter, indicate the desirability of giving special attention to the feeding of ewe lambs in range flocks. Problems needing further attention, to determine how far the rancher can afford to go in giving special attention to his ewe lambs, are outlined.

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HERITABILITY OF WEANING WEIGHT AND STAPLE LENGTH IN RANGE RAMBOUILLET LAMBS

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TRAITS in farm livestock and in other farm animals are frequently described as "highly" or "lowly" heritable depending on how closely parents and offspring, full-sibs, or other close relatives resemble each other. Heritability is important to the breeder because it represents the proportion of the gain which is transmitted to the offspring through selected parents and is generally useful in estimating probable genetic improvement (Lush, 1935). In addition, estimates of heritability are essential in planning efficient breeding systems (Wright, 1939) and in determining the relative emphasis due each of several traits when breeding animals are selected (Hazel, 1943).

Estimates of heritability for weaning weight and staple length in range Rambouillet lambs are reported in the present paper.

Range sheep have the dual function of producing meat and wool, hence traits which reflect capacity to produce these in quantity and quality have economic value in breeding for range sheep improvement. Weaning weight of lambs is important because income from meat production largely comes from the sale of lambs soon after weaning, and because it is correlated with mature body weight (Terrill, 1939). Staple length at weaning age is important because lambs are culled soon after weaning, at which time some measure of subsequent wool production is needed. Lambert, Hardy and Schott (1938) and Pohle (1942) reported correlations of 0.65 and 0.67, respectively, between weanling and yearling staple length.

Description of Data

The data used in this study were taken as a routine part of the breeding program of the Western Sheep Breeding Laboratory, Dubois, Idaho. All Rambouillet lambs which were raised to weaning age in 1941 and 1942 were included in each phase of the study for which the data were suitable. Practically no culling took place before weaning age. Data were available for 2183 lambs and for 892 of their dams.

Some of the lambs were produced in inbred lines and others by top-crossing inbred sires to noninbred ewes. Most of the lines were in the early stages of inbreeding, and one sire was used each year in each line. In the top-cross group, young sires from the inbred lines were being progeny-tested for subsequent use in inbred lines. For these reasons the lambs were

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separated on the basis of year of birth and system of mating and the data analyzed in four separate groups.

Weaning weight and staple length for both dams and offspring were adjusted for sex, age of dam, type of birth and rearing, age at weaning, and percent inbreeding according to the differences found in these same data by Hazel and Terrill (1945). In addition, the records of dams were adjusted for average yearly differences in weaning weight and staple length according to the year in which they were born.

Analytical Method

The form of analysis used in the study is shown in table 1. The total variance and convariance in each sample was separated into components as

TABLE 1. COMPOSITION OF MEAN SQUARES AND CROSS-PRODUCTS FOR DAMS AND OFFSPRING

Source of variation	Degrees of freedom	Mean squares		Cross-products
		Offspring	Dams	Dams and offspring
Between sires	$n-1$	$B+kA$	$B'+kA'$	cov (b)$+k$ cov (a)
Within sires	$n(k-1)$	B	B'	cov (b)

outlined by Fisher (1936) and shown in table 1. The component B represents the variance between lambs by the same sire, and A the additional variance between lambs by different sires; hence lambs with different sires have the variance $A+B$. Similar interpretations apply to the components for dams (A' and B') mated to the same or different sires. The component of covariance "cov(*b*)" is the covariance common to a dam and her offspring within the sire group, while cov(*a*) is that common to all dams and offspring in the sire group; hence cov(*a*)+cov(*b*) is the covariance between dam and offspring in a population consisting of an infinite number of sire groups.

Table 2 shows the relations between the components of variance and covariance and the genetic (G) and environmental (E) variances for three systems of mating. The genetic variance (G) represents that due to the effects of genes which combine additively according to the multiple factor hypothesis, and the environmental variance (E) represents the combined effects of environment, dominance, and epistasis. Wright's (1921) inbreeding coefficients are represented by f' and f for parents and offspring, respectively. In noninbred populations, half-sibs each receive a sample half of their sire's inheritance; hence, $A=(1/4)G$. In top-crosses with inbred sires, half-sibs receive some additional common inheritance from their in-

bred sire; hence, $A = \left\{\frac{1+f'}{4}\right\} G$. In one-sire inbred lines, the dams are related to each other and also to the sire; hence, $A = \left\{\frac{1+f'+6f}{4}\right\} G$. The remaining relations can be established by similar reasoning, or, more precisely, by the biometric relations between relatives as set forth by Wright (1921). The assumption must be made that environmental differences among dams and offspring are randomized to derive the relations shown in table 2. The

TABLE 2. RELATIONS BETWEEN COMPONENTS OF VARIANCE AND COVARIANCE AND THE GENETIC AND ENVIRONMENTAL VARIANCE FOR THREE SYSTEMS OF MATING

Source	Component	Noninbred populations	One-sire inbred lines	Top-crosses
Variance of offspring	A	$(1/4)\,G$	$\frac{(1+f'+6f)}{4} G$	$\frac{(1+f')}{4} G$
	B	$(3/4)\,G+E$	$\frac{(3-f'-2f)}{4} G+E$	$\frac{(3-f')}{4} G+E$
	$A+B$	$G+E$	$(1+f)\,G+E$	$G+E$
Variance of dams	A'	0	$2fG'$	0
	B'	$G'+E'$	$(1+f'-2f)\,G'+E'$	$G'+E'$
	$A'+B'$	$G'+E'$	$(1+f')\,G'+E'$	$G'+E'$
Covariance of dams and offspring	cov (a)	0	fG'	0
	cov (b)	$(1/2)\,G$	$\frac{(1+f'-2f)}{2} G$	$(1/2)\,G$
	cov (a)+cov (b)	$(1/2)\,G$	$\frac{(1+f')}{2} G$	$(1/2)\,G$

effect of inbreeding upon the observed sources of variance is given in greater detail by Dickerson (1942).

Lush (1940) suggested several methods of estimating heritability, of which two, the half-sib correlation and intra-sire regression of offspring on dam, are best adapted to the present data. These statistics are equivalent to $\frac{A}{A+B}$ and $\frac{\text{cov (b)}}{B'}$, respectively, in the symbols of tables 1 and 2. In non-

inbred populations they must be multiplied by 4 and 2, respectively, to provide estimates of heritability, as shown in table 3. Estimates of heritability, if unbiased, must be equivalent to the ratio of the genetic variance to the total variance (which is $\frac{G}{G+E}$ in the present case). Consequently, the formulas for the half-sib correlation and intrasire regression of offspring on

TABLE 3. FORMULAS FOR ESTIMATES OF HERITABILITY FOR THREE SYSTEMS OF MATING

Method of estimation	Noninbred populations	One-sire inbred lines	Top-crosses
Half-sib correlation	$\frac{4A}{A+B}$	$\frac{4}{1+f'+6f} \cdot \frac{A}{B+A\left\{1-\frac{4f}{1+f'+6f}\right\}}$	$\frac{4}{1+f'} \cdot \frac{A}{A+B}$
Intra-sire regression of offspring on dam	$\frac{2\,\mathrm{cov}\,(b)}{B'}$	$\frac{2}{1+f'-2f} \cdot \frac{\mathrm{cov}\,(b)}{B'+2\frac{(2f-f')\,\mathrm{cov}\,(b)}{1+f'-2f}}$	$\frac{2\,\mathrm{cov}\,(b)}{B'}$

dam must be modified as shown in table 3 when used on data from one-sire inbred lines or top-crosses. The factors are $\frac{4}{1+f'}$ and 2 for top-crosses and $\frac{4}{1+f'+6f}$ and $\frac{2}{1+f'-2f}$ for inbred lines with additional slight modifications in the denominators in the latter case, as compared with 4 and 2 in noninbred populations.

The standard error of the half-sib correlation is $\frac{B(B+kA)}{(A+B)^2\sqrt{(1/2)(k-1)kn}}$ and it may be multiplied by the factor 4, $\frac{4}{1+f'}$, or $\frac{4}{1+f'+6f}$ to obtain the standard error of heritability as estimated by this method from noninbred, top-crossed, or one-sire inbred line samples, respectively. The standard error of the intra-sire regression of offspring on dam is $\sqrt{\frac{BB'-\mathrm{cov}\,(b)^2}{(B')^2(nk-n-1)}}$ and it may be multiplied by the factor 2, 2, or $\frac{2}{1+f'-2f}$ to obtain the appropriate standard error of heritability as estimated by this method. The standard

errors for one-sire inbred lines are not exactly correct because of the slight change in the denominator necessary with both the half-sib and the intra-sire regression methods, but the error is slight at the low levels of inbreeding encountered in the present study.

In the present data, there were 286 pairs of twins among the 2183 lambs. An adjustment for their presence appeared necessary, particularly in the half-sib method, because twins are genetically full-sibs. It was found, however, that the 286 full-sib comparisons were too small a proportion of the total 22,555 comparisons within sire groups to have an appreciable effect upon estimates of heritability. Consequently, the formulas given in table 3 were used without adjustment for the presence of twins.

Results

The results of the analyses for the weaning weights of the 2183 lambs are summarized by groups in table 4. The mean square between sires is significantly larger than that within sires in both inbred groups but is not significantly larger in the top-crossed groups. Two reasons for this difference

TABLE 4. MEAN SQUARES FOR WEANING WEIGHT OF 2183 LAMBS

Group	Year	Source of variation	Degrees of freedom	Mean squares	Constants
One-sire inbred lines	1941	Total	698	88.93	$k = 18.83$
		Between sires	36	224.48**	$f' = .026$
		Within sires	662	81.56	$f = .066$
	1942	Total	909	75.58	$k = 24.47$
		Between sires	36	298.85**	$f' = .041$
		Within sires	873	66.38	$f = .076$
Top-crosses	1941	Total	304	50.89	$k = 9.81$
		Between sires	30	62.73	$f' = .054$
		Within sires	274	49.59	$f = 0$
	1942	Total	268	53.92	$k = 9.22$
		Between sires	28	71.01	$f' = .053$
		Within sires	240	51.93	$f = 0$

** Signifies probability of chance occurrence $< .01$.

are evident from the preceding analysis. First, the component A is present in the mean square between sires in proportion to k,[2] the number of off-

[2] Since all of the sires did not have the same number of lambs, k is slightly smaller than the average number of lambs per sire. The formula used for figuring k is $= \frac{(\Sigma k)^2 - \Sigma(k)^2}{\Sigma k(n-1)}$.

spring per sire, and this number is larger in the two inbred groups. Second, the inbreeding of the lambs makes the component A larger in the inbred groups.

The results of the variance and covariance analyses of the weaning weights of the 892 dams and their offspring are summarized by groups in table 5. The average weights of the dams mated to different sires were sig-

TABLE 5. MEAN SQUARES AND COVARIANCES FOR WEANING WEIGHTS OF 892 DAMS AND OFFSPRING

Group	Year	Source of variation	Degrees freedom	Mean squares		Cross-products	Constants
				Dams	Offspring	Dams & offspring	
One-sire inbred lines	1941	Total	194	64.23	92.54	− 0.87	$f' = .036$
		Between sires	31	114.00**	194.00**	2.00	$f = .097$
		Within sires	163	54.76	73.24	− 1.41	
	1942	Total	411	69.57	72.91	12.55	$f' = .048$
		Between sires	36	111.78**	174.25**	40.36	$f = .101$
		Within sires	375	65.51	63.18	9.88	
Top-crosses	1941	Total	119	44.55	44.13	6.02	$f' = .054$
		Between sires	26	31.85	36.62	− 1.19	$f = 0$
		Within sires	93	48.11	46.24	8.03	
	1942	Total	164	55.21	40.52	8.50	$f' = .053$
		Between sires	28	54.39	42.29	−18.07	$f = 0$
		Within sires	136	55.38	40.15	13.97	

** Signifies probability of chance occurrence $< .01$.

nificantly different in the two inbred groups, as might be expected due to the inbreeding of the dams. In the top-crosses, the random-bred dams were sorted to the various sires by lot, so nonsignificance of the mean squares between sire-groups for the dams is a reasonable circumstance. The reason for the small negative covariance between dams and offspring within sires in table 5 is not clear. It may be due to sampling errors or to some unknown environmental circumstance which disturbed the usually positive relation between the weaning weights of dams and offspring as seen in the other groups.

The estimates for heritability of weaning weight are shown for each group of data in table 6. The estimates by the half-sib method were calculated from the data in table 4 and those for the intra-sire regression method from the data in table 5, the appropriate formulas from table 3 being applied in each

case. The range in the estimates is large as compared with the size of the sampling errors, but is hardly large enough to support an hypothesis that even the most extreme estimates differ significantly. Although the negative estimate is obviously an error, it should not be disregarded entirely. Errors in either direction cannot be recognized with certainty unless they are less than zero or greater than unity; hence it is probable that some of the larger estimates err in the positive direction. Since there is no other reason to question the accuracy of the data in the 1941 inbred group, it seemed no more than reasonable that this estimate be used in calculating an average for all the data.

TABLE 6. ESTIMATES OF HERITABILITY AND STANDARD ERRORS FOR WEANING WEIGHT

Group	Year	Half-sib method		Intra-sire regression method	
		Heritability	Standard error	Heritability	Standard error
One-sire inbred lines	1941	0.243	0.082	−0.063	0.215
	1942	.363	.067	.343	.118
Top-crosses	1941	.100	.124	.334	.204
	1942	.146	.145	.504	.140
Average		.269	.045	.339	.077

The average heritability for the four groups of data by the half-sib method is 0.269 and by the intra-sire regression method is 0.339. These averages were calculated by weighting each of the individual estimates by the reciprocal of its squared standard error. This method is not without disadvantages, but it does in general give greater weight to those estimates which are based on the greatest amount of data. The averages for the two methods agree as well as can be expected in view of their sampling errors. When weighted as before the average estimate for the heritability of weaning weight from all of the data is $0.30 \pm .04$.

Two of the inbred lines in 1941 and three in 1942 were started with foundation sheep that had exceptionally long staple. The foundation animals were purposely selected for this trait and the lambs in these lines had longer than average staple in 1941 and 1942. They were left out of the analyses by the half-sib method since their presence might be expected unduly to magnify sire differences. They were retained in the intra-sire re-

gression analyses because there was no reason to think that differences in staple length within the long-staple lines would be inherited any differently than in lines started with unselected stock.

The results of the analyses for staple length of the 2060 remaining lambs are summarized in table 7. Sire differences are highly significant in each group, and this alone indicates that staple length is more highly heritable than weaning weight. The variance and covariance analyses for the 892 dams and offspring are summarized in table 8.

TABLE 7. MEAN SQUARES FOR STAPLE LENGTH OF 2060 LAMBS

Group	Year	Source of variation	Degrees of freedom	Mean squares	Constants
One-sire inbred lines	1941	Total	653	0.1909	$k = 18.62$
		Between sires	34	.5396**	$f' = .054$
		Within sires	619	.1718	$f = .056$
	1942	Total	831	.2506	$k = 24.34$
		Between sires	33	1.2933**	$f' = .053$
		Within sires	798	.2074	$f = .076$
Top-crosses	1941	Total	304	.1665	$k = 9.81$
		Between sires	30	.4167**	$f' = .025$
		Within sires	274	.1391	$f = 0$
	1942	Total	268	.1951	$k = 9.22$
		Between sires	28	.4044**	$f' = .043$
		Within sires	240	.1707	$f = 0$

** Signifies probability of chance occurrence $< .01$.

The estimates of heritability of staple length were calculated from the data in tables 7 and 8 in accordance with the formulas in table 3. They are shown with their standard errors in table 9. The estimates agree more closely and are generally higher than those for weaning weight. In this case, the average estimate by the intra-sire regression method is a little smaller than that by the half-sib method. The average based on all of the data is $0.40 \pm .05$.

A comparison of the estimates of heritability for weaning weight in table 6 with those for staple length in table 9 indicates that there is no tendency for the estimates to be higher with one system of mating than with the other, or with one method of estimation than with the other.

Discussion, and Application of Results

Inbreeding within closed lines and top-crossing inbred sires to noninbred

females tends to increase the half-sib correlation, as compared with the corresponding correlation in noninbred populations. With one-sire inbred

TABLE 8. MEAN SQUARES AND COVARIANCES FOR STAPLE LENGTH OF 892 DAMS AND OFFSPRING

Group	Year	Source of variation	Degrees of freedom	Mean squares		Cross-products	Constants
				Dams	Offspring	Dams & offspring	
One-sire inbred lines	1941	Total	194	0.1634	0.2195	0.0430	$f' = .036$
		Between sires	31	.1539	.3932**	.1163	$f = .097$
		Within sires	163	.1652	.1865	.0291	
	1942	Total	411	.1964	.2335	.0351	$f' = .048$
		Between sires	36	.2988*	.7289**	.0952	$f = .101$
		Within sires	375	.1865	.1859	.0296	
Top-crosses	1941	Total	119	.1521	.1394	.0149	$f' = .054$
		Between sires	26	.1092	.2066*	−.0049	$f = 0$
		Within sires	93	.1641	.1206	.0205	
	1942	Total	164	.1927	.1870	.0325	$f' = .053$
		Between sires	28	.1507	.2570	−.0556	$f = 0$
		Within sires	136	.2013	.1726	.0506	

* Signifies probability of chance occurrence <.05.
** Signifies probability of chance occurrence <.01.

TABLE 9. ESTIMATES OF HERITABILITY AND STANDARD ERRORS FOR STAPLE LENGTH

Group	Year	Half-sib method		Intra-sire regression method	
		Heritability	Standard error	Heritability	Standard error
One-sire inbred lines	1941	0.296	0.094	0.410	0.196
	1942	.490	.115	.371	.120
Top-crosses	1941	.642	.215	.250	.177
	1942	.491	.206	.503	.153
Average		.410	.065	.387	.077

lines even a small amount of inbreeding results in a marked increase in the half-sib correlation for traits which are at all highly heritable. The intra-sire

regression of offspring on dam is decreased in one-sire inbred lines but is not affected by top-crossing, as compared with that in noninbred groups.

The estimates of heritability for weaning weight and staple length in the four groups of data were not consistently high or low in any group or with either the half-sib or the intra-sire regression methods. This indicates that the effect of the mating systems, although in opposite directions for the two methods, were adequately discounted by the formulas in table 3. It also supports (in these particular data) the validity of the assumption concerning the randomness of treatment differences between offspring of each sire and between each dam and her offspring.

The average estimates for heritability of weaning weight and staple length at weaning age were $0.30 \pm .04$ and $0.40 \pm .05$, respectively. Measurements for both traits were adjusted for differences in sex, age of dam, type of birth and rearing, age at weaning and percent inbreeding according to the differences found by Hazel and Terrill (1945). These environmental factors accounted for about 50 and 20 percent, respectively, of the variance in the two traits. Therefore, it seems probable that heritability would have been about 0.15 for weaning weight and 0.32 for staple length in unadjusted data.

Terrill and Hazel (1943) reported estimates of 0.40 for body weight and 0.36 for staple length of yearling Rambouillet ewes. Phillips *et al.* (1940) reported a number of regression coefficients for daughters on dams which averaged 0.25 and 0.23 for the two traits at yearling age. These figures suggest that the heritability of body weight increases from weanling (125 days) to yearling (400 days) age, while that for staple length remains relatively constant.

Replacement rates are limited by the rate of reproduction and the age of usefulness in range sheep to about 70 percent for ewe lambs and about 3 percent for ram lambs. These rates correspond to selection differentials of 0.50 and 2.27, respectively, in normally distributed populations. Since the standard deviation of weaning weight is 8.48 pounds and heritability is 0.30, the expected gain per generation would be $(0.30)(8.48)(0.50+2.27)/2 = 3.5$ pounds if all selection were directed toward the improvement of weaning weight alone. That expected for staple length, for which the standard deviation is 0.46 cm., would be $(0.40)(0.46)(0.50+2.27)/2 = 0.25$ cm. Since the average length of generation in sheep is a little more than 4 years, these estimates indicate that the maximum improvement per year would be less than 1 pound in weaning weight or about 0.06 cm. in staple length.

A number of factors must be considered in planning a breeding program so that maximum economic gain is realized (Hazel, 1943). First, several traits

are likely to be important enough to merit some attention. These traits will usually differ in relative economic importance, in heritability, and in their relationships with each other. Second, all of the traits cannot be measured at the same age. For example, fleece weight cannot be measured before the first shearing at yearling age, while ewe productivity, or "mothering ability," cannot be measured before the first parturition. Hazel and Lush (1942) have shown that with n equally important, uncorrelated traits, the gain possible in any trait is only $1/\sqrt{n}$ times as great as if all selection were directed toward improving only one trait. Thus it is possible that the maximum gains deduced above for weaning weight and staple length must be reduced by $\frac{1}{2}$ to $\frac{1}{4}$ to conform to the amount of attention weaning weight and staple length should receive in a properly balanced breeding program. It is hoped that some of these points can be clarified by studies now under way.

Summary

Estimates of heritability were calculated for weaning weight and staple length at weaning age from data taken on the breeding flocks of the Western Sheep Breeding Laboratory, Dubois, Idaho. The data consisted of records taken on 2183 lambs born in 1941 and 1942 and on 892 dam-offspring pairs.

The methods of estimation were based on the half-sib correlation and the intra-sire regression of offspring on dam, modified to discount the effects of non-random mating systems. Some of the lambs were produced in inbred lines and some by top-crossing inbred sires to noninbred females. The effect of these systems is to increase the half-sib correlation as compared with that expected in noninbred populations. Inbreeding causes a decrease, but top-crossing has no effect upon the intra-sire regression of offspring on dam.

Estimates of heritability by the half-sib and by the intra-sire regression methods were reasonably consistent, indicating that the effects of the mating systems had been adequately discounted.

The average estimates for heritability of weaning weight and staple length were $0.30 \pm .04$ and $0.40 \pm .05$, respectively. Since the records had been adjusted for several environmental factors, which accounted for about 50 and 20 percent of the variance in weaning weight and staple length, respectively, it appears that in unadjusted data heritability of weaning weight and staple length may be no more than 0.15 and 0.32, respectively.

The maximum gain expected from selecting for either weaning weight or staple length alone is about 0.9 pound or 0.06 cm. per year, respectively. When allowance is made for emphasis on other traits, as is necessary in a properly balanced breeding program, it seems probable that the gains actually made will not be more than $\frac{1}{2}$ or $\frac{1}{4}$ of the above figures.

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THE INHERITANCE OF PROLIFICACY IN SWINE[1]

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IMPROVEMENT of livestock, in one or several characteristics, through selection depends not only on the genetic variability of the population from which selections are made, but also on the proportion of available animals that are required for breeding purposes. Satisfactory reproduction, or prolificacy, therefore is basic to the whole program of progress in animal breeding because it results in larger populations from which a given number of animals may be selected.

In order that selection for prolificacy may be effective, animals saved as breeders must be able to transmit this quality to their offspring. Progress through selection is equal to that proportion of the selection differential, or the difference between the selected and the total populations, that is due to heritable differences in the genotypes of these sows.

Wright (1921) has demonstrated methods of dividing the total variance of a characteristic into genetic and environmental portions. In these procedures all causes of variation that are not due to differences in genotype are grouped together as environmental. Thus the portion of variance is divided into heritable and non-heritable fractions. The heritable fraction contributes to the likeness of related animals and when expressed as percent of the total variance is called "heritability." All of the genetic variance contributes to "repeatability," the correlation between recurrent expressions of a characteristic by the same animal.

There is evidence that workers believe heritability of fertility, within a species, breed, or line, to be very small (Pearson, 1911; Wright, 1922). Estimates of heritability of litter size in swine range from 0.10 to 0.44 as reported in the review by Lush and Molln (1942). These workers considered that the estimate of 0.17 from their own data was in close agreement with other findings. Additional reports by Hetzer, Lambert, and Zeller (1940), Hallqvist (1942), and Olbrycht (1943) are within the range of earlier reports. The wide range in estimates suggests the sampling errors to which these estimates are subject.

The purpose of this study was to obtain further information on both heritability and repeatability of litter size in swine.

[1] Paper No. 2232, Scientific Journal Series of the Minnesota Agricultural Experiment Station in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, United States Department of Agriculture. The results reported in this paper are part of a comprehensive study of the factors affecting productivity in swine which is being conducted by the University of Minnesota under the direction of Dr. L. M. Winters. The author is indebted to Dr. R. E. Comstock for guidance in the statistical procedures. This is the second paper pertaining to fertility from a thesis submitted to the Graduate Faculty of the University of Minnesota in partial fulfillment of the requirements for the degree of doctor of philosophy.

Materials and Methods

The data for this study were taken from records of swine raised in the Minnesota swine breeding project in cooperation with the Regional Swine Breeding Laboratory from 1937 to 1943, inclusive. The management of the herds from which these data were gathered has been described elsewhere (Stewart, 1945). Estimates of heritability of litter size were obtained from: (1) correlation between paternal half sibs, (2) correlation between full sibs, and (3) intra-sire regression of the litter size of daughters on that of their dams. In each of the three methods only first litters were considered.

Data and Discussion

Correlations Between Paternal Half Sibs, and Between Full Sibs

In this analysis total variance was divided so that the differences in litter size could be assigned the following: A. Differences between groups of gilts. B. Differences within the groups between gilts by different sires. C. Differences between gilts by the same sire but from different dams. D. Differences between gilts that were litter mates.

TABLE 1. ANALYSES OF VARIANCE FOR AGE OF DAM IN MONTHS (a), LIVE PIGS FARROWED (d), AND TOTAL PIGS FARROWED (d_1), DUE TO DIFFERENCES IN GROUPS, SIRES, DAMS, AND LITTER MATES

Source of variation	d.f.	Mean squares		
		d^2	a^2	d_1^2
Between groups	53	24.02**	3.92**	27.30**
Between sires within groups	41	7.37	1.93**	8.41
Between litters within sires	203	5.67	0.75**	6.72
Between gilts within litters	312	5.86	0.15	6.22

** Highly significant.

The analyses of variance shown in table 1 indicate highly significant differences in litter size and age at first farrow, between groups. The groups referred to in the analysis were composed of animals belonging to the same inbred line and raised in the same year and season. Highly significant differences are also revealed in the age at which gilts by different sires, and, by the same sire but different dams, farrow their litters. This may introduce a bias in estimates made by this method which is based on the assumption that all environmental effects are randomly distributed. Since the extent of possible bias is unknown, no correction was attempted for age differences between gilts in this analysis, as suggested by earlier work (Stewart, 1945).

The correlations were computed from analyses of variance of litter size given in table 1. The method employed has been used by several other work-

ers (Stonaker and Lush, 1942; Rasmussen, 1942; Nordskog *et al.*, 1944; and others). The theoretical composition of the mean squares is given in table 2, where

V = the variance among full-sibs.

W = the additional variance among paternal half-sibs resulting from genetic differences among dams or environmental influences in excess of those causing variance among full-sibs.

X = the additional variance among animals having neither the same sire or dam resulting from genetic differences among sires or environmental influences in excess of those causing variance among paternal half-sibs.

Y = the additional variance among animals from different groups resulting from genetic differences between inbred lines or environmental influences in excess of those causing variance within lines.

TABLE 2. ANALYSIS OF MEAN SQUARES INTO THEIR THEORETICAL COMPONENTS

Source of variation[1]	d.f.	Mean squares	Theoretical composition
Between groups	53	A=	$V+W\frac{610}{298}+X\frac{610}{95}+Y\frac{610}{54}$
Between sires within groups	41	B=	$V+W\frac{610}{298}+X\frac{610}{95}$
Between litters within sires	203	C=	$V+W\frac{610}{298}$
Between gilts within litters	312	D=	V

[1] Total number of pigs—610. Total number of litters 298. Total number of sires—95. Total number of groups 54.

The numerical coefficients of W, X and Y are the average number of animals per litter, per sire, and per line, respectively, in the data used. They are approximations to the more precise values that would have resulted from use of the formulas developed by Hetzer, Dickerson and Zeller (1944). In view of the large sampling errors to which the mean squares and their components are subject they are good enough approximations for all practical purposes. Since, in these data, Y included variance arising from environmental differences between stations and years, it was decided to estimate heritability as percent of total variance within lines and years ($V+W+X$). The intra-line, intra-year correlation between paternal half-sibs is equal to

$\frac{X}{V+W+X}$ and the intra-line, intra-year correlation between full-sibs is equal to $\frac{X+W}{V+W+X}$.

Wright (1921) showed that when the variance from environmental sources is no greater among half-sibs or among animals having both different sires and different dams than among full-sibs, the correlation between half-sibs is equal to one-fourth heritability ($h^2/4$) and the correlation between full-sibs is equal to one-half heritability ($h^2/2$).

TABLE 3. ANALYSIS OF THE COMPONENTS OF VARIANCE

Component	Portions of variance			
	Live pigs farrowed		Total pigs farrowed	
	Actual units	Percent of total	Actual units	Percent of total
T	1.47	19.3	1.67	19.9
X	0.27	3.6	0.26	3.1
W	0.00	0.0	0.24	2.9
V	5.86	77.1	6.22	74.1
Total	7.60	100.0	8.39	100.0

The numerical estimates of V, W, and X are presented in table 3. They lead to the following correlations and estimates of heritability.

Estimates of heritability of litter size from paternal half-sib and full-sib correlations from these data result as follows:

	Pigs farrowed alive		*Total*	
Paternal half-sib	$r = .044$	$h^2 = .176$	$r = .039$	$h^2 = .156$
Full-sib	$= .044$	$= .088$	$= .074$	$= .148$

Estimates from Intra-Sire Regression of Daughters on Dams

Doubling the intra-sire regressions of the records of daughters on the records of their dams is, according to Lush and Straus (1942), the method best suited for estimating heritability from data where the dams are a selected group and the sire himself does not express the characteristic being studied.

In this analysis the gilts were grouped in such a way that those in a group were by the same sire, of equal age, and from dams that were born in the same year and season and farrowed their first litters in the same year and season. Analyses were made dividing variance and covariance of dams and

daughters' litters into portions between and within groups.[2] The regression coefficients were computed from the within group values. Since all year and line variance was between groups, the resulting estimates of heritability were on an intra-year, intra-line basis as was the case for the estimates described in the foregoing section. The entire analysis involved 80 groups, as defined above, containing a total of 475 gilts from 250 dams. Average litter sizes are given in table 4.

TABLE 4. MEAN SIZE OF FIRST LITTERS OF DAUGHTERS AND DAMS IN INTRA-SIRE REGRESSIONS, SEPARATED BY LINES

Line	Average litter size farrowed			Average litter size farrowed			No. of groups
	No. of dams	Alive	Total	No. of daughters	Alive	Total	
Minn. #1	73	9.75	10.32	156	8.69	9.22	20
BS NW	27	7.96	8.15	53	6.08	6.53	8
ML	28	7.39	7.89	45	6.11	6.56	10
Crossed lines	15	7.60	7.73	26	8.35	8.73	3
BS WC	18	7.94	8.00	31	8.16	8.26	6
WL	21	7.95	8.05	33	7.12	7.21	8
V	21	9.52	9.71	41	8.12	8.22	8
Crossed lines	6	9.17	9.33	6	7.67	7.67	3
C_1 Cent.	13	8.15	8.31	27	5.56	5.85	4
C_2	5	7.80	8.00	16	4.69	5.06	2
M	11	7.82	7.91	18	5.39	5.39	4
C	8	7.50	7.63	16	5.81	6.13	3
G	4	7.25	7.25	7	5.43	5.43	1
Total	250	8.53	8.83	475	7.35	7.69	80

As a check on the corrections made for the effects of age, it was decided to correct the number of pigs farrowed for both daughter and her dam to a standard age of 12 months, using the values found from an earlier study (Stewart, 1945).

The estimates of heritability from the regression coefficients calculated from these data may be summarized as shown at the top of the next page.

The regression coefficients are not significantly different from zero at 170 degrees of freedom, the number of dams contributing to the analysis minus the number of boar groups. Nevertheless they yield the best estimates avail-

[2] Litter size of dam was weighted according to the number of her daughters.

Litter size of dam weighted by number of daughters	Coefficients of regression	Standard error	Estimate of heritability
Uncorrected for age			
Live pigs farrowed	.075	.114	.150
Total pigs farrowed	.066	.113	.132
Corrected for age			
Live pigs farrowed	.079	.114	.158
Total pigs farrowed			.136

able for the heritability of litter size regardless of the size of their standard errors. Reliable estimates of the heritability for litter size will probably come from an accumulation of estimates from regressions based on numbers insufficient to demonstrate significance in themselves.

Correction of litter size for live pigs farrowed of all females to the basis of farrowing at 12 months resulted in estimates very close to those from the uncorrected data adjusted to the 3 percent of variance accountable to age differences. The estimate from corrected data was .158 while the adjusted estimate from uncorrected data was .155.

Estimates of Repeatability

Repeatability of the size of litter was studied to obtain an estimate as to the upper limits of heritability. The estimates of repeatability were obtained from correlations between the size of first and second litters, or from the regression coefficients of the size of the second litter on the size of the first. Since sows are saved for a second farrowing on the basis of their performance with their first litters, the correlation may be expected to underestimate repeatability, while the regression of the size of the second litter on the size of the first litter gives an unbiased estimate.

The data included records on 221 females that had produced a second litter. Of these 175 were from various inbred lines and line crosses within the Poland China breed, and 46 were Minnesota No. 1 females. One hundred forty-five of the total number farrowed their second litter when approximately 24 months old, the remaining 76 farrowing their second litters at about 18 months. Since there are differences in fertility between the lines the analysis of variance was between and within groups of females farrowing in the same line during the same year and season. The correlations and regressions were determined from the within group component of the analysis. Estimates were made for both total and live pigs farrowed, corrected and uncorrected for age differences of the dams at the time of farrowing their first litters. The simple and partial correlations and regressions from these data are presented in table 5.

Since the gilts were selected to farrow a second litter on the basis of their performance at the first farrowing the variance in the size of the first litter would be expected to be smaller than the variance of the second litter size from the same females, if there are no differences in residual effects due to depletion during the previous farrowing and lactation periods.

In an effort to determine if the total number of pigs in the first litter furnished a better criterion for predicting the number of live pigs in the second litter than live pigs in the first litter, correlations and regressions were also calculated between the number of pigs farrowed alive in the second litter and the total number of pigs farrowed in the first, both corrected and uncorrected for age differences between the dams as gilts. The differences between

TABLE 5. INTRA-LINE INTRA-YEAR CORRELATIONS (r) AND REGRESSIONS (b) OF THE NUMBER OF PIGS FARROWED IN SECOND LITTERS (c) ON THE NUMBER OF PIGS FARROWED IN FIRST LITTERS (d)

Grouping	No. of females	Uncorrected		Corrected for age	
		r_{cd}	b_{cd}	$r_{cd.a}$	$b_{cd.a}$
Live pigs in second on live pigs in first, all sows all litters	221	.074	.088	.098	.128
Live pigs in second on total pigs in first, all litters	221	.071	.085	.104	.114
Total pigs in second on total pigs in first, all litters	221	.090	.104	.116	.133

all of these regressions were very small and insignificant. This indicates that the number of live pigs in the first litter predicts the number of live pigs in the second at least equally as well as the total number of pigs in the first litter.

The most reliable estimates of repeatability from these data should be the partial regressions of second litter size on the size of the first litter corrected for age differences of the dams at first farrowing. These estimates are .128 for live pigs and .133 for total pigs farrowed, which agree with the report of Hetzer *et al.* (1940) on the results of 17 years of inbreeding Chester White swine.

Summary

Estimates of heritability of litter size in swine were determined by three methods for both total pigs farrowed and pigs farrowed alive. All of the estimates fell within the range 8.8 percent to 17.6 percent. The mean estimates were 13.6 percent from live pigs farrowed and 14.5 percent from total pigs.

Estimates of repeatability were 12.8 percent for live pigs and 13.3 percent for total pigs farrowed.

There is close agreement between these estimates of heritability and repeatability and it may be concluded that variations in size of litter due to inheritance must be due very largely to the average effects of genes.

Heritability of litter size determined from these data is close to 14 percent. Since the average coefficient of inbreeding of the females used in this study was 0.19, the genetic variance may be expected to be 19 percent less than that of an outbred population. Thus on the basis of an outbred population the heritability of the number of pigs farrowed is estimated at approximately 17 percent.

According to results obtained in this and other studies relating to heritability of litter size progress in increasing fertility by selection in an outbred stock low in fertility would be very slow if simultaneous selection for other characteristics continued. The most rapid progress would come from a greatly increased selection differential, such as would result from an outcross with individuals selected on the basis of fertility from a breed or line known to be high in fertility.

The most rapid progress in increasing fertility within a breed should be expected to result from the development of fertile inbred lines and their use in outcrossing throughout the breed.

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RELATION OF PRODUCTION OF DAIRY COWS TO THE NUTRIENTS FED

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THE question of profit from the feeding of concentrates has long been of prime importance in the dairy enterprise. It has been difficult to determine at what feeding level the highest profits would be obtained because the relationship between input and output had not been sufficiently explored by carefully conducted feeding experiments.

The recent study made by the Bureau of Dairy Industry in co-operation with ten state experiment stations (Jensen *et al.*, 1942) for a period of years has provided a more complete body of data than had hitherto been assembled making possible a more accurate determination of the manner in which output varies with input. Jensen and his co-authors showed that the relationship between input and output is curvilinear and that it follows the formula for diminishing returns.

The Delaware Agricultural Experiment Station was one of those co-operating with the Bureau of Dairy Industry in the co-operative work reported by Jensen *et al.* (1942). Baker and Tomhave (1944) of that Station have issued an independent bulletin using their own data in which they maintain that the relationship is a straight line and not curvilinear. They found that the output increased 1.46 pounds 4 percent fat corrected milk for each pound increase in the total digestible nutrients fed above maintenance. They draw the conclusion that if the value of one pound of total digestible nutrients fed is less than that of 1.46 pounds of milk it will pay to feed as much as the cows will consume. This would not be the case if the relationship were curvilinear.

Headley (1943), using the data published in U. S. Technical Bulletin 815, showed that there is a logarithmic relationship between input and output which makes possible close estimates of the effect on production of any change in the amount of total digestible nutrients fed above maintenance. This relationship is not affected by the basic productive ability of the cows. It is necessary to know only one feeding level and the production obtained from it for any one group of cows to be able to calculate the production to be obtained from any change in the amount of nutrients fed. It is not even necessary to know the production at the known feeding level to calculate the change in production that will be obtained at any other feeding level. In the present paper the logarithmic method is discussed in further detail and comparisons are made with straight line correlation.

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The Logarithmic Method

Within the limits of observations in the experiments reported by Jensen *et al.* (1942), production varied quite consistently with the mantissa of the logarithm of nutrients consumed above maintenance. The method of calculation is illustrated in table 1. The data in columns P and N were taken from table 4 of Jensen *et al.*

TABLE 1. DETERMINING EFFECT OF FEEDING LEVEL ON PRODUCTION BY LOGARITHMIC METHOD

Group No.	Average production per cow	TDN over maintenance	Mantissa*	Mean of P less mean of log N	Estimated production lbs.	Deviation of estimate from actual, lbs.
	P	N	Log N	C	Log N+C	D
1	6128	2531	4033		6408	+280
2	7521	3109	4926		7301	−220
3	8113	3788	5784		8159	+ 46
4	8319	3825	5826		8201	−118
5	8499	4107	6135		8510	+ 11
Avg.	7716		5341	2375	7716	

* In making calculations only the mantissa of log N is used. The decimal point is moved 4 places to the right providing the nutrients fed lie between 1,000 and 10,000 pounds a year. For example, the log of 2531 is 3.4033. The decimal point is moved to the right 4 places and the characteristic is dropped.

C is a constant for any one group of cows or for any other group with the same basic productive capacity. For an average of a number of determinations, as in table 1, C is obtained by subtracting the mean of log N from the mean of actual production. For a single group, C is obtained by subtracting log N from P. The constant C represents the estimated production when N equals 1,000, that is when the nutrients fed above maintenance are 1,000 pounds a year. The value of C is not affected by changing the level of feeding, but at any given feeding level it is high with high producing and low producing cows. C may be looked upon as an efficiency factor representing the basic productive ability of the individual cow or group of cows, whichever is being used. The factor C cannot be accurately obtained from partial lactations. The data in table 1 are charted in curve 1 of figure 1.

Method of Estimating Effect of Change in Feeding Level

The amount of change in production to be expected from a change in the feeding level may be calculated in two ways as illustrated by the following example. If an increase is made in the feeding level from 2,200 pounds above maintenance to 2,750 pounds the increase in N is 550 pounds and the second feeding level is 125 percent of the first.

Method 1. Mantissa of log 125 = 969 lbs. increase in production
Method 2. Mantissa of log 2750 = 4393
2200 = 3424

969 lbs. increase in production.

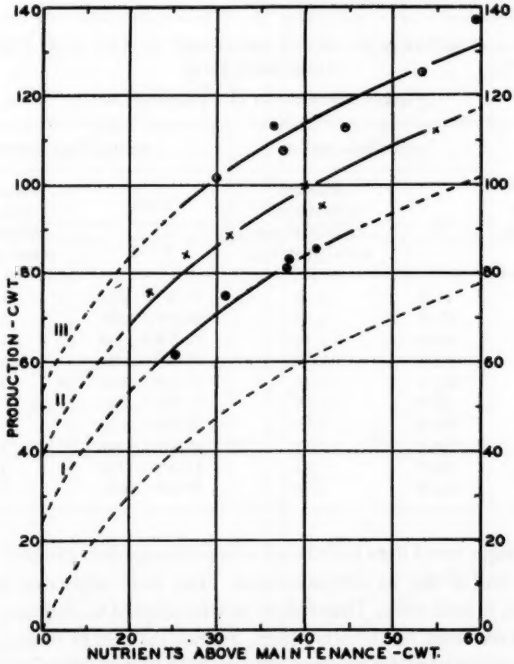

Figure 1. Relation of Production of 4 percent Fat Corrected Milk to Nutrients Fed Above Maintenance. The data for curves I, II and III were taken from tables 4, 3, and 11–4 of U.S.D.A. Technical Bulletin 815 (Jensen *et al.*, 1942). The heavy, solid lines in these curves represent light, medium and heavy producing groups of cows. The respective C values for these curves are 23.7, 39.0 and 53.9. The bottom broken line, or basic curve, is drawn through the points representing the mantissas of the logarithms of the numbers at the bottom representing feed input over maintenance. Each curve representing production is equidistant vertically throughout its length from the basic curve.

The figure 969 represents the estimated increase in production of 4 percent FCM that would be secured by increasing the nutrients fed over maintenance from 2,200 to 2,750 pounds.

Curved Vs. Straight Trend Lines

The test as to whether the relationship between input and output is a straight or a logarithmic curved line may be made by comparing results from all applicable tables presented by Jensen *et al.* (1942). This has been done in table 2 and the accuracy of estimates are measured by the standard deviation of estimates from actual production.

TABLE 2. COMPARISON OF LOGARITHMIC CURVE AND STRAIGHT LINE METHODS

(Figures represent cwt of 4 percent FCM)

Table number in Jensen *et al.* (1942)	Logarithmic method		Straight line method	
	C	Standard deviation of estimates from actual prod. cwt.	Value of Y $a+bx$	Standard deviation of estimated from actual prod. cwt.
1	43.8	4.25	51.9+1.255x	4.46
2	52.6	4.46	58.7+1.308x	6.85
3	39.0	3.23	54.7+1.054x	2.48
4	23.7	1.88	26.6+1.457x	2.21
5	39.1	2.40	58.0+1.000x	2.00
10	36.0	1.87	51.8+1.070x	1.09
11-1	23.9	5.80	39.8+1.003x	3.40
11-2	29.1	1.52	41.0+1.170x	1.16
11-3	39.5	3.24	52.4+1.150x	3.40
11-4	53.9	4.20	80.9+ .820x	5.20

The straight trend lines had the advantage of a smaller standard deviation in exactly half of the 10 determinations. They were calculated for best fit for the data in each table. They follow no rule adapted to all groups of cows.

The curved lines, on the other hand, are not the best fit to each group of data but are adjusted for position only as indicated by the C values. The slopes of the curved lines are always the same while the slopes of the straight lines vary from .82x to 1.457x. If the latter were given a uniform slope their accuracy would be considerably less than that of the logarithmic curves. For purposes of predicting production at different feeding levels the straight-line method would be less accurate than the logarithmic method.

Curved lines could be fitted to each group of data with somewhat more accuracy than the uniform log curves. This was done for the production charts presented by Jensen *et al.* (1942), but in the present study the author was attempting to devise a universal mathematical equation that would be applicable to all feeding levels within the limits of these experiments. No reasonably accurate straight-line formula can be formed to fit the data from

all the experiments published in the tables of Jensen *et al.* (1942), while the log curves appear to be equally accurate at any level of feeding.

In figure 1 it will be seen that the difference in C value between groups of highest and lowest efficiency was 30.2, indicating a difference in the production of the highest and lowest producing groups of 3,020 pounds of milk

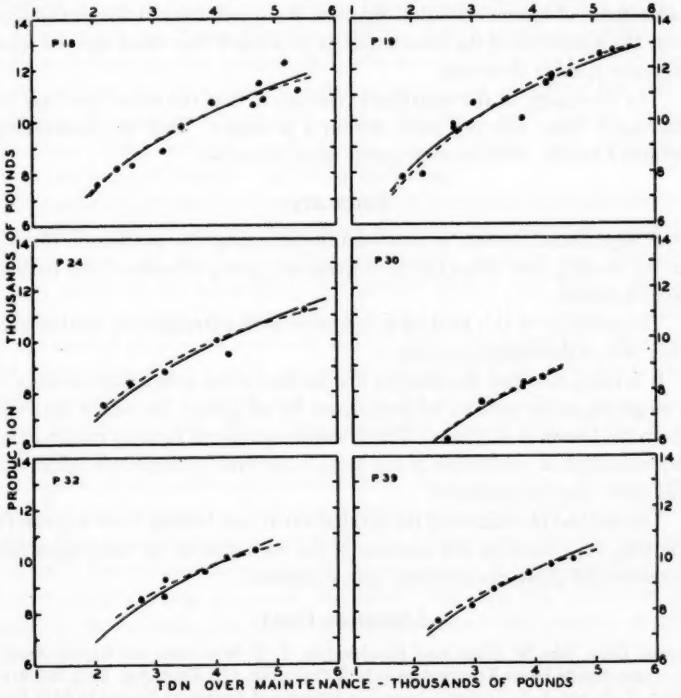

Figure 2. Effect of Feeding Level on Production of Groups of Cows of Varying Basic Productive Ability. (Data from Jensen *et al.*, 1942). Broken lines are in same position as shown in that publication. Number in upper left hand corner gives table page in the original publication. These are lines of best fit. Solid lines are calculated by the logarithmic method. They vary only as to vertical position. Their slopes are the same in each chart.

a year at any given feeding level. There can be greater differences in efficiency between individual cows but it is not likely that much greater differences will be found for large groups.

Jensen *et al.* (1942) used the curve of diminishing returns suggested by Spillman (1933). Those curves are compared with the curves derived by the

logarithmic method in figure 2, using the data from six of the tables from Jensen *et al.* Theirs are shown by the broken lines and the logarithmic curves by the solid lines. The departure of the logarithmic curves from the broken line curves may be assumed to represent a measure of the error of the method. The error however for all practical purposes is insignificant. The correspondence is very good for groups of highest efficiency (figure 2, P-19) as it is for those of lowest efficiency (figure 2, P-30) and there is the probability that the separation of the lines would be still less if they were derived from a greater number of records.

The advantage of the logarithmic formula is that the entire line may be calculated when only one point within it is known. With the diminishing returns formula, three or more points must be known.

Summary

A logarithmic method is presented of estimating the production of milk at any feeding level when the production of a group of cows at one feeding level is known.

The accuracy of this method is compared with a straight line method and the curve of diminishing returns.

It is concluded that the straight line method is not sufficiently accurate if a single equation were to be formulated for all groups for which data are given by Jensen *et al.* (1942). The diminishing-returns formula requires the determination of production of any group at several feeding levels before the full curve can be calculated.

The method of estimating the production at any feeding level is given in the text. It is based on the mantissa of the logarithm of the total digestible nutrients fed above maintenance, plus a constant.

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THE NUTRITIVE VALUE OF CORN COBS IN BEEF CATTLE RATIONS

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THE nutritive value of corn cobs as fed in corn-and-cob meal to fattening cattle has been a disputed question of long standing. Feedlot results vary from the one extreme that cobs are of little or no value to the other extreme that they are as valuable as legume hay or slightly less valuable than the corn grain itself (Otis, 1904; Mumford, 1905; Allison, 1917; Vaughan, 1927; Gerlaugh, 1928; Peters, 1933; Thalman and Cathcart, 1934; Gerlaugh and Rogers, 1936; King 1938, 1940).

Digestion experiments with cattle and other ruminants, although meager in number, have consistently been more favorable to a substantial feeding value in corn cobs than have feedlot experiments. Thalman and Cathcart (1934) compared the digestibility of a ground shelled corn ration with a ground ear-corn ration for steers and concluded that "The presence of bulk in the form of cob, or cob and husk, did not have any appreciable effect on the digestibility of the rations as a whole." Digestion trials with sheep and goats conducted by (Lindsey, 1893; Emery and Kilgore, 1894, Fraps, 1919, 1924) indicate that cobs have a total digestible nutrient value of 46.2 or a value approaching that of hays.

In much of the earlier experimental work, the value, if any, of cobs was regarded rather vaguely as a bulk factor contributing to the ration as a whole rather than to any appreciable nutrients which might be obtained from the cob itself. Recent evidence relative to the physiology of ruminant digestion (micro-biology) points to a new conception regarding the utilization of coarse or bulky feeds, and these experiments reopen the question of cob utilization.

The purpose of this paper is to present digestion and feedlot measurements of the value of corn cobs in beef cattle rations.

Methods

The methods employed in the digestion trials were more or less standard procedure, in which a basal ration without corn cobs was compared with a similar ration to which cobs had been added. Cob utilization was determined by subtracting the digestible nutrients of the non-cob fraction of the cob ration from the total digestible nutrients of the ration. The fraction subtracted was assumed to be utilized similarly to the basal or non-cob ration.

[1] Resigned February 1944.

In most cases, two or three such comparisons were made simultaneously by using one steer on each of four rations during a given collection period. Three additional collection periods followed in which the four rations were shifted to different steers until all four animals had consumed the four rations in four respective periods. These four collection periods constituted a digestion trial.

Fifteen-day collection periods were used, preceded by an adjustment period of 6 days or longer. Feces and urine samples were weighed daily, the daily samples of each were then thoroughly mixed and a 10 pct. aliquot sample of each was saved until the end of the period. These aliquot composite samples were mixed, and suitable sized samples were preserved with toluene and by refrigeration until analyzed chemically. The analyses (A.O.A.C. methods), for the most part, included the nutrients necessary for the determination of total digestible nutrients. In one trial, metabolizable energy was included and the total digestible nutrients were estimated from the digestible dry matter. The energy determinations were made directly with an oxygen bomb calorimeter, with the exception of the gaseous losses which were estimated by the method of Kriss (1930).

The feedlot trials included four series of three lots each in which ground shelled corn was compared with (1) ground ear corn and (2) with ground ear corn plus additional cobs. The percentage of cob in the corn-and-cob meals was approximately 20 and 33, respectively. Two of the three-lot series (one of calves and one of yearlings) were fed in large groups of 20 head each. One three-lot series (36 calves) was fed individually, while the other three-lot series (36 yearlings) was fed in small groups of 4 head each.

The calves were choice grade Herefords and were fed for 252 days (1942–43); the yearlings were well-fleshed Herefords and were fed for 196 days (1943–44). Two pounds of mineralized soybean oil meal were fed daily to each steer. Mixed hay and corn or corn-and-cob meal were full fed to the small and large-group lots and were limited fed in the individually fed lots. The mineralized soybean oil meal contained 2 pounds steamed bonemeal, 2 pounds limestone, and 1 pound salt in each 100 pounds of soybean oil meal. The mixed hay was of medium quality which would grade No. 2. The corn used in both years' work was grown in 1942. It was ground medium fine with a hammer type feed grinder so that the cob particles were not sorted out by the steer in the feed bunk.

Experimental Results

Digestibility of Corn Cobs at Three Intervals of the Fattening Period.

The first digestion experiment was designed to measure the value of corn cobs when calves weighing 450 pounds started on feed, when they were

midway on full-feed and weighing 650 pounds, and again when they were on full-feed and weighing 900 pounds. The rations consumed are presented in table 1. Corn and cob consumptions in the late period were not as high as planned, since it was found impossible to maintain full-feeding under diges-

TABLE 1. DAILY RATIONS FED CALVES DURING 1940–41

Feed	Period					
	Early		Middle		Late	
	Without cob	With cob	Without cob	With cob	Without cob	With cob
	pounds	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
Hay (cut alfalfa)	3.5	3.5	3.5	3.5	3.50	3.5
Protein supplement	0.5	0.5	1.5	1.5	1.50	1.5
Corn (ground)	2.5	2.4	7.5	7.2	8.86	8.4
Cob (ground)	—	0.6	—	1.8	—	2.1
Total	6.5	7.0	12.5	14.0	13.86	15.5

tion stall conditions. In view of this circumstance, the utilization of corn cobsduring the late period was more representative of the mid-feeding condition than that of the intended full-feeding period.

The composition of the rations fed is listed in table 2.

TABLE 2. COMPOSITION OF RATION INGREDIENTS

Feed	Component of feed				
	Dry matter	Protein	Crude fiber	Ether extract	Ash
	percent	*percent*	*percent*	*percent*	*percent*
Hay (cut alfalfa)	90.58	13.32	32.92	1.88	5.20
Protein supplement	91.34	43.39	6.08	5.43	10.86
Corn (ground)	86.92	8.75	2.09	4.18	1.55
Cob (ground)	89.42	1.92	33.21	0.32	1.31

The value obtained with corn cobs in the early period, table 3, were higher than those obtained in the mid period. A further decrease in cob utilization in the late period as compared with the mid period was not secured, rather the reverse relationship existed. Whether the results would have been lower in this late period had the objective of full-feeding conditions been reached cannot be answered by this experiment. However, the feedlot results, to be discussed later, point to a decreased utilization of the cob as the fattening period progresses.

Digestibility of corn cobs using varying amounts in fattening steer rations.

The second digestion experiment, composed of two trials, purposed the feeding of different amounts of corn cobs in corn-and-cob meal mixtures. The basal ground corn rations in each trial, table 4, was compared with (1)

TABLE 3. DIGESTIBLE NUTRIENTS PER 100 POUNDS CORN COBS. (AVERAGE OF 4 STEERS)

Period	Component of feed		
	Dry matter	Protein (N×6.25)	T. D. N.
	pounds	*pounds*	*pounds*
Early	61.11	2.48	58.53
Middle	43.43	−3.14	42.86
Late	54.68	−0.34	57.65
Average	53.07	−0.33	53.01

TABLE 4. DAILY RATIONS

Feed	Type of ration			
	No cob in ear corn	Half cob in ear corn	Regular cob in ear corn	Double cob in ear corn
600-pound calves, 1942				
	pounds	*pounds*	*pounds*	*pounds*
Hay (chopped alsike)	3.5	3.50	3.50	3.50
Protein supplement	1.5	1.50	1.50	1.50
Corn (ground)	7.0	6.59	6.14	5.11
Cob (ground)	—	0.73	1.54	3.41
Total	12.0	12.32	12.68	13.52
Yearlings, 1942–43				
Hay (chopped alsike)	3.5	3.50	3.50	3.50
Protein supplement	1.5	1.50	1.50	1.50
Corn (ground)	7.0	7.00	7.00	7.00
Cob (ground)	—	0.78	1.76	4.66
Total	12.0	12.78	13.76	16.66

a corn-and-cob meal ration having one-half the normal amount of cob contained in ear corn, with (2) the regular amount of cob in corn-and-cob meal, and with (3) double the amount of cob in ear corn. Hay and supplement were

fed in equal amounts in all rations. In the first trial of this experiment the total amount of corn-and-cob meal rations fed daily was somewhat more than the total weight of the ground shelled corn rations. The difference was estimated so that the grain in each ration, as well as the total ration, would be fed at the same plane of nutrition, or so that each would have approximately the same T. D. N. value. The plane of nutrition was considerably above maintenance but less than full-feeding conditions.

The composition of the ration ingredients is presented in table 5.

TABLE 5. COMPOSITION OF RATION INGREDIENTS

Feed	Component of feed				
	Dry matter	Protein (N×6.25)	Crude fiber	Ether extract	Ash
	percent	*percent*	*percent*	*percent*	*percent*
Hay (chopped alsike)	87.17	11.85	27.75	1.24	4.99
Protein supplement	91.29	42.88	7.25	3.81	15.43
Corn (ground)	85.56	9.01	2.50	1.59	1.37
Cob (ground)	91.33	2.01	34.11	0.30	1.28

The results obtained in the first trial of this experiment, table 6, average about the same as the results presented for the first experiment. The digestibility of the cob in the high-cob ration was consistently lower with all four steers than the similar values for cobs in both the lesser-cob level rations.

The second trial of this experiment was largely a repetition of the first in which similar feeds and the same steers were used after they had grown to yearlings. The amounts of ground corn and ground cob fed differed somewhat from that used in the first trial, as can be seen in table 4. In the second trial the total amount of ground corn fed as well as of hay and supplement, was the same in all lots. Although this feature of the experimental set-up had some advantages it had the disadvantage of comparing two rations at different planes of nutrition; *i.e.*, 12 pounds of feed fed in the no-cob ration and 16.66 pounds of feed in the high-cob ration. This tends to decrease the apparent digestibility of the cob, because in the determination of cob utilization the non-cob fraction of the cob ration is given too high a value, based on the findings of Forbes *et al.* (1930) and Mitchell *et al.* (1932). A comparison of the results (cob T. D. N. 43.5) obtained in this experiment with the results (cob T. D. N. 52.7) of the preceding trial bears out this contention. It would therefore seem that, if the cob had not been given the experimental handicap in the second trial, its nutritive value would have compared favorably with the first trial of this experiment.

TABLE 6. DIGESTIBLE NUTRIENTS PER 100 POUNDS CORN COBS

Type of cob ration	Component of feed		
	Dry matter	Protein (N×6.25)	T. D. N.[1]
600-pound calves, 1942			
	pounds	*pounds*	*pounds*
Half cob in ear corn	60.08	−0.69	59.50
Regular cob in ear corn	61.63	−0.29	61.89
Double cob in ear corn	36.70	−3.29	36.72
Average	52.80	−1.42	52.70
Yearlings, 1942–43			
Half cob in ear corn	38.21	—	37.95
Regular cob in ear corn	46.97	—	46.65
Double cob in ear corn	46.20	—	45.89
Average	43.79	—	43.50

[1] T. D. N. estimated for yearling group.

Digestibility of Corn Cobs Fed with Alfalfa Hay

The over-all digestibility in the preceding trials (T. D. N. values) indicated a fattening value in corn cobs similar to the fattening value of legume hay. With this in mind and for the purposes of determining the digestibility of corn cobs using a different basal ration, the following test was made. The basal ration, tables 7 and 8, consisted of good quality alfalfa hay. The three experimental rations contained 10, 20, and 30 pct. of ground cobs, respectively. The total daily feed consumption, as well as the estimated T. D. N. intake, was constant. The amount fed was about equivalent to a maintenance ration.

TABLE 7. DAILY RATIONS FED 475-POUND CALVES DURING 1943

Feed	Amount of cob in ration			
	No cob	10 percent	20 percent	30 percent
	pounds	*pounds*	*pounds*	*pounds*
Hay (cut alfalfa)	5.72	5.14	4.58	4.00
Corn cobs (ground)	—	0.58	1.14	1.72
Total	5.72	5.72	5.72	5.72

TABLE 8. COMPOSITION OF ALFALFA HAY AND CORN COBS

Feed	Component of feed			
	Dry matter	Protein (N×6.25)	Crude fiber	Gross energy per 100 lbs.
	percent	*percent*	*percent*	*therms*
Hay (cut alfalfa)	90.10	16.19	27.62	188.6
Corn cobs (ground)	93.10	2.09	33.10	186.8

The results, table 9, were very uniform throughout each level of cob intake and for each steer on a given level of cob feeding. The average estimated T. D. N. value of 58.0 was somewhat higher for corn cobs when they were fed in the hay ration than when fed in a ration containing hay, protein supplement, and corn. This, in part, may be due to the influence of the basal ration; however, it is felt that these higher values were influenced by the low plane of nutrition at which the cobs were tested.

TABLE 9. DIGESTIBLE NUTRIENTS AND METABOLIZABLE ENERGY PER 100 POUNDS CORN COBS. (AVERAGE 4 STEERS)

Feed	Component of feed			
	Dry matter	Protein (N×6.25)	Metab. energy	Estimated T.D.N.
	pounds	*pounds*	*therms*	*pounds*
Corn cobs (10 pct. ration)	58.39	−1.04	78.0	57.97
Corn cobs (20 pct. ration)	59.06	−1.55	92.8	58.63
Corn cobs (30 pct. ration)	57.82	−0.72	87.8	57.41
Average	58.42	−0.77	86.2	58.00

Digestibility of Corn Cobs Fed With Small Amounts of Dried Buttermilk

The simplest and most direct method of determining digestibility of corn cobs is to feed the cob separately, rather than to incorporate it into a ration and then determine digestibility by the subtraction method. An attempt was made to feed ground corn cobs without additional feeds, but insufficient feed was consumed to make this determination possible.

As a substitute technique a small amount (10 pct.) of dried buttermilk was added to the cobs; the digestibility of the milk was considered to be 100 pct. This assumption is not entirely correct, but, fair consumption of corn

cobs (5 pounds daily) was thus obtained. Since the buttermilk was probably not completely digested, the resulting digestion values for the corn cobs were depressed rather than enhanced by this technique.

TABLE 10. DIGESTIBLE NUTRIENTS PER 100 POUNDS CORN COBS

Steer No.	Dry matter	Estimated T. D. N.
	pounds	*pounds*
9	51.64	51.26
10	43.78	43.46
11	55.80	55.39
12	48.51	48.15
Average	49.93	49.57

The average dry matter and estimated T. D. N. values, table 10, for corn cobs compare very favorably with similar values in which the cob was fed as a component part of a ration.

Feedlot Results With Corn Cobs Fed to Calves During 1942–43

Apparent digestibility figures of feeds obtained with ruminants are at times subject to misinterpretations, especially where small amounts are fed and/or when digestibility is determined on a feed incorporated in a ration in which associative feed influences may be present. In addition to and in conjunction with the digestion trials, feedlot experiments were employed in measuring the feeding value of corn cobs. In this way, it was presumed that one method of experimentation could be compared with the other and the validity of the results assessed.

The general feedlot set-up has been previously described. Further details of the procedure, along with the results of the first test, are presented in table 11. Although the three 12-head lots were fed individually, no attempt is made at this time to present the individual data in detail. It should be pointed out, however, that this method of feeding resulted in a lower feed intake, especially of the hay, when compared to the group-fed cattle. The gains and the feed costs per unit of gain were also reduced correspondingly in the individually fed lots.

The average daily gains made by the 20-steer groups (1.97, 1.99 and 1.93 pounds) were surprisingly close. Since the hay and supplement fed was not greatly different in these lots, the amounts of these two feeds required to put on 100 pounds of gain were about equal. This fortunate circumstance permitted a direct comparison between the feed requirement of the corn

grain and amount of corn cobs needed in putting on a unit of gain. The grain saved (see table 11) in putting on 100 pounds gain in the two group-fed lots (572–508 and 572–444) was 64 and 128 pounds, respectively. In saving this amount of grain, 115 and 202 pounds of cobs were required. By dividing the grain saved by the cob required, estimates of 55.6 and 63.4 percent were obtained for the value of the cob as compared with the corn grain itself.

TABLE 11. FEEDLOT RESULTS WITH CALVES USING CORN COBS IN FATTENING RATION. STEERS WERE FED FOR 252 DAYS, IN 1942–43

Items compared	Group fed			Individually fed		
	Ground shelled corn	Corn+ cob meal	Corn+ double cob meal	Ground shelled corn	Corn+ cob meal	Corn+ double cob meal
No. steers started	20	20	20	12	12	12
Weight, initial (lb.)	486	490	488	479	480	479
Av. daily ration (lb.)						
Hay (mixed)	4.16	4.19	3.82	2.79	2.80	2.78
Mineralized S.B.O.M.	2.00	2.00	2.00	2.00	2.00	2.00
Corn (ground)	11.26	10.12	8.56	8.80	7.66	6.36
Cob (ground)	—	2.29	3.88	—	1.74	2.89
Av. daily gain (lb.)	1.97	1.99	1.93	1.72	1.76	1.62
Feed Cwt. gain (lb.)	212	210				
Hay (mixed)	212	210	199	162	159	171
Mineralized S.B.O.M.	102	100	104	116	114	123
Corn (ground)	572	508	444	512	436	392
Cob (ground)	—	115	202	—	99	178
Value of cobs in terms of shelled corn (pct.).	—	55.6	63.4	—	76.8	67.4
Dressing percentage	61.0	60.2	59.6	59.0	57.3	55.7
Top choice carcass	9	5	11	—	—	—
Medium choice carcass	7	13	6	—	—	—
Low choice carcass	2	2	2	—	—	—

These estimates assume that the gains made in each lot were comparable throughout. That this assumption is not entirely correct is suggested in the dressing percentages of the three lots (61.0, 60.2, and 59.6). The differences are not large and, therefore, would not reduce greatly the estimated cob values if the reduced dressing percentage of the cob lots is a reflection of greater fill. If, on the other hand, the reduced dressing percentage reflects a difference in carcass finish, then a somewhat greater mark-off in the above

cob values would be justified. The exact significance of the dressing percentage data was not directly determined. There is evidence, however, to support the contention that the difference obtained were in part, if not entirely, due to fill. In this connection, the carcass grade data (table 11) indicate a slightly higher grade in the cob lots, although there was some feeling on the part of the graders that the cob-fed cattle were not quite as fat as the ground-shelled-corn cattle. Further evidence on the significance of the dressing percentage consists of rumen digestion studies (unpublished data) which show a heavier ballast of material in this compartment of the digestive tract when cattle are fed on corn-and-cob meal than when fed on ground shelled corn.

The results of the individually-fed calves support and confirm those of the group-fed cattle. The cob replacement values (76.8 and 67.4 percent) of the corn grain were higher in the 12-steer lots than in the 20-steer lots (55.6 and 63.4 percent). This difference largely disappears when proper account is taken of the larger differences in dressing percentage in the individually-fed lots (3.3 percent.) than occurred in the group-fed lots (1.4 percent). This difference is believed associated with the condition of the cattle at slaughter time. No carcass grades were taken on the 36 head of individually-fed cattle.

Feedlot Results With Corn Cobs Fed to Yearlings During 1943–44

The second-year (1943–44) feedlot experiment with corn cobs was largely a repetition of the first year's work. Similar feeds were fed and in about the same ratios. There were, however, a few differences in the two tests which are worthy of note. Yearlings were used rather than calves. The feeding period was reduced from 252 days to 196 days. However, the yearling cattle attained approximately the same degree of finish as the longer fed calves of the previous year.

The three 12-steer groups were fed in small pens of 4 head each rather than individually as was done in 1942–43. The results are not given in detail on these small groups, but rather the total data, table 12, are presented for 12-steer groups.

Two pounds of mineralized soybean oil meal per steer was fed daily in all lots. Mixed hay, although full fed and not purposely equalized between lots, was consumed in the same amount (4.60 pounds per steer daily) in all lots. Corn-and-cob meal and ground shelled corn were full fed, the former being consumed in a little larger amount than the latter.

The average daily gains made in the three 20-steer groups, 1.94, 1.91 and 1.87 pounds, respectively, were very similar, with a slight advantage

for the ground-shelled-corn lot. A similar relationship in gains existed in the 12-steer groups, 2.01 pounds daily in the ground-shelled-corn group and 1.98 pounds daily in each of the cob lots.

The replacement value of ground cobs in terms of ground shelled corn was computed by the method described in the first experiment. When compared to the utilization of the corn grain itself, the two 20-steer lots appar-

TABLE 12. FEEDLOT RESULTS WITH YEARLING STEERS USING CORN COBS IN FATTENING RATION. THE STEERS WERE FED FOR 196 DAYS, IN 1943–44

Items compared	Group fed			3 groups of 4 head each		
	Ground shelled corn	Corn+ cob meal	Corn+ double cob meal	Ground shelled corn	Corn+ cob meal	Corn+ double cob meal
No. steers started	20	20	20	12	12	12
Weight, initial (lb.)	704	704	717	711	706	704
Av. daily rations (lb.)						
Hay (mixed)	4.60	4.60	4.60	4.60	4.60	4.60
Mineralized S.B.O.M.	2.00	2.00	2.00	2.00	2.00	2.00
Corn (ground)	14.30	12.70	10.73	14.19	12.51	10.52
Cob (ground)	—	2.84	4.80	—	2.80	4.71
Av. daily gain (lb.)	1.94	1.91	1.87	2.01	1.98	1.98
Feed Cwt. gain (lb.)						
Hay (mixed)	236	240	247	227	230	230
Mineralized S.B.O.M.	103	105	108	100	101	101
Corn (ground)	739	666	578	706	631	531
Cob (ground)	—	149	259	—	141	238
Value of cobs in terms of shelled corn (pct.)	—	48.9	62.2	—	53.2	73.5
Dressing percent	62.33	62.02	61.15	62.73	62.32	62.27
Top choice carcass	9	8	10	5	6	7
Choice carcass	7	8	4	5	6	4
Good carcass	4	4	4	2	0	1

ently utilized the cob to 48.9 and 62.2 percent, respectively. In the 12-steer groups, the cob replacement value of corn was 52.7 percent in one case and 73.5 percent in the other.

The dressing percentages were slightly lower in the cob-fed cattle than in the ground-shelled-corn steers, see table 12. Carcass grades between groups were very similar. No superiority was detected in the carcasses of the ground-corn over the corn-and-cob produced dressed beef.

Discussion.

The digestion experiments and feedlot measurements reported above consistently pointed to a substantial feeding value in corn cobs when fed to beef cattle. The average total digestible nutrients in corn cobs measured in 13 digestion comparisons, using four steers per experiment, was 51.6 pounds in each 100 pounds of corn cobs. This value, when compared with the total digestible nutrients in corn grain (80.6 for No. 2 yellow corn, Morrison 1936), indicates that ground cobs have an average fattening value for steers equivalent to 64 percent of that found in the corn grain itself. This average figure compares favorably with the average replacement value of corn cobs for ground corn as determined in the feedlot trials. In eight feedlot comparisons, using 192 steers, corn cobs had an average apparent replacement value of 62 percent of the total nutritive value of ground shelled corn.

The parallelism between the average results obtained in the digestion and feedlot trials suggest the accuracy of the results under the average experimental conditions imposed. That corn cobs will have a similar feeding value under all feeding conditions is doubtful. Previous experimental work (cited in introduction) point to this conclusion. Also, there was a fair-sized deviation from the average value of corn cobs within both the digestion and the feedlot experiments.

Such a deviation is encountered in all biological measurements; however, there is reason to expect a greater variation in the nutritive value of a feed whose type is similar to corn cobs than in many other feeds. The chemical composition of cobs (high in cellulose and related compounds) is such that if appreciable nutritive value is obtained from the cob it must be digested to some extent in some way other than through the use of body enzymes. This other method of digestion is commonly accepted as being associated with the micro-organisms present in the alimentary canal. Therefore, corn-cob utilization may be subject not only to variations in the processes of digestion concerned with the animal proper, but also to variations which are associated with digestion by micro-organisms living within the animal.

No attempt is made at this time to enumerate or evaluate some of the possible influencing factors involved in corn-cob utilization. However, additional investigations now in progress offer encouragement in this respect. The average result obtained in the reported trials is, therefore, regarded as tentative rather than final. On this basis, it would seem that corn cobs have an appreciable and a practical feeding value when fed as ground ear corn to fattening steers under average conditions similar to the ones prevailing in these experiments.

Assigning a replacement value of 62 for cobs in terms of ground corn, a bushel of ground ear corn would be worth 15 percent more than a bushel of ground-shelled-corn for fattening cattle. If more cob than the percentage normally occurring in ground ear corn were fed, the "15 percent" figure would be somewhat increased.

The purpose of the experiments in which larger amounts of cobs were fed was not to encourage this procedure in practice, but rather, to determine experimentally a more accurate value of corn cobs as they occur in regular corn-and-cob meal. In times of corn shortages, however, or under some farm conditions, the use of additional corn cobs in the steer ration might be attractive.

These practical considerations in the comparative value of ground ear corn and ground shelled corn do not take into account the pork produced as a by-product of the grain rations fed the steers. Data upon this phase of the problem were collected. It is not satisfactory, in all respects, but it does indicate that if additional pork is produced in the ground-shelled-corn lots it is far less important than the additional value obtained by the steer from the cob in the corn-cob lots.

Summary

The nutritive value of corn cobs obtained in 13 digestion comparisons with four steers each, averaged 51.6 pounds of total digestible nutrients in each 100 pounds of corn cobs. This average figure suggests that cobs for cattle are 64 percent as valuable as the grain itself for energy or fattening purposes. In feedlot experiments, consisting of eight comparisons using a total of 192 cattle, the corn cob replacement value of the corn grain averaged 62 percent. This value is regarded as tentative rather than as final with respect to all situations of cob utilization. The chemical nature of corn cobs, along with variations obtained in this and other experiments points to fluctuations in cob utilization, the partial cause of which is believed related to micro-biological digestion in which the influencing factors are little understood at present.

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COMPARISON OF DIFFERENT AMOUNTS OF PROTEIN SUPPLEMENT FOR WINTERING BEEF COWS ON FOREST RANGE IN THE SOUTHEASTERN COASTAL PLAIN[1]

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NUMEROUS tests have been made on wintering beef cows on the western range, but very little work of this type has been done on forest range in the Southeastern Coastal Plain. If beef cows can be wintered satisfactorily in this area on native forage, plus a reasonable amount of protein concentrate, it should prove a practical and economical method of wintering. In most cases, the number of cattle that can be carried by a producer is limited by his winter feed supply. Therefore to meet the increased demand for beef during the critical war period it is essential to determine if breeding herds can be wintered satisfactorily on forest range. It is also important, of course, to determine the optimum amount of protein concentrates that should be fed.

Because of the possibilities of supplementing forest ranges in the Southeastern Coastal Plain, feeding tests were started in North Carolina during the winter of 1941–42 and are still being continued (Foster and Biswell, 1942). The primary purpose of these tests has been to study the effects of wintering cows on native forest range when they were fed different levels of protein supplements, taking into consideration winter and summer gains of cows and calves, death losses, percentage of calf crops, and any other items of practical importance. Snapp (1939) forcibly emphasizes the fact that the plane of nutrition on which cows are wintered greatly affects their future usefulness.

Forest Ranges in the Coastal Plain

Millions of acres of forest range in the Southeast are used for grazing, either seasonally or yearlong (Biswell *et al.* 1942, and Campbell and Rhodes, 1944). However, a large percentage of the cattle confined to this range should probably be fed supplemental feeds during the winter. There are over nine million acres of this forest range in the Coastal Plain of North Carolina where the present studies are under way (Biswell and Foster, 1942). It

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[2] J. E. Foster and E. H. Hostetler, North Carolina Agricultural Experiment Station and Bureau of Animal Industry, United States Department of Agriculture; and H. H. Biswell, Appalachian Forest Experiment Station, Forest Service, United States Department of Agriculture. Acknowledgment is made to R. E. Comstock for assistance with the statistical analyses.

should be mentioned, however, that in many places the undergrowth of brush is too thick for much grazing, and poisonous plants may occasionally cause trouble (Shaw *et al.* 1943).

Forest ranges in this state that are best suited for grazing contain a growth of reeds or switch cane (*Arundinaria tecta*), native grasses, hardwood shrubs, and vines. The feeding tests are being made in areas of this kind. The summer grazing capacity varies, in general, from 10 to 15 acres per animal unit, but in the best reed areas it may be as high as 2 acres per animal unit (Foster, *et al.* 1937). However, for winter grazing, though of shorter duration, slightly more acres are required per animal.

Kind and Composition of Forage Eaten

During these tests the native forage eaten by the cattle has consisted of the following estimated amounts: Reeds or switch cane; 30 percent; other grasses and grass-like plants, 30 percent; browse from shrubs, vines and broad-leaved trees, 30 percent; and broad-leaved herbs, 10 percent. Pine trees in the areas were not browsed. As a result of the grazing and trampling by the cattle the forest fire hazard was greatly reduced. This is one of the important benefits from grazing in the Coastal Plains, but is difficult to evaluate in terms of dollars and cents.

Chemical analyses[3] show the native forage to be nutritious during the summer but during the winter it is deficient in total digestible nutrients, especially in protein (fig. 1). Similar results were reported by Biswell *et al.* (1943, 1944). Because of this protein deficiency it would seem that the most practical supplement to feed on forest range would be a concentrate such as cottonseed meal or soybean oil meal, both home grown products. In addition to correcting the deficiencies in the native forage, such concentrates can be transported more easily than bulky feeds. Since it was thought that the forage might be deficient in several of the essential minerals (Becker *et al.* 1931, 1933), a rather complete mixture containing calcium, phosphorus, salt, iron, copper, and cobalt, has been available to the cattle at all times.

Feeding Trials

Thus far, three feeding trials have been completed, each of which will be discussed separately in this report. Cows and three-year-old heifers, bred to calve between February 1 and May 1, were used. The cattle were rotated between forest ranges and weighed every 28 days.

Grade cattle, principally of Hereford breeding, were used in the trials. In studies already reported, Hostetler *et al.* (1936) found that it was more practical to graze cattle of this type on forest range than native unimproved cattle, such as are often found on Southeastern ranges.

[3] Analyses made by T. S. Boggess, Jr., Bureau of Animal Husbandry, U. S. Department of Agriculture.

First Trial

In the first trial two groups, each consisting of 27 cows and three-year-old bred heifers, were fed two and four pounds of 36 percent crude protein cottonseed pellets or meal per head daily from January 16, 1942, to May 8, 1942 (table 1). Both groups calved normally and weaned an average of nearly 70 percent calf crop. The cows in the two-pound group, however, lost considerably more weight during the feeding period than did those in the four-pound group, and they weaned slightly fewer calves. The calves in the

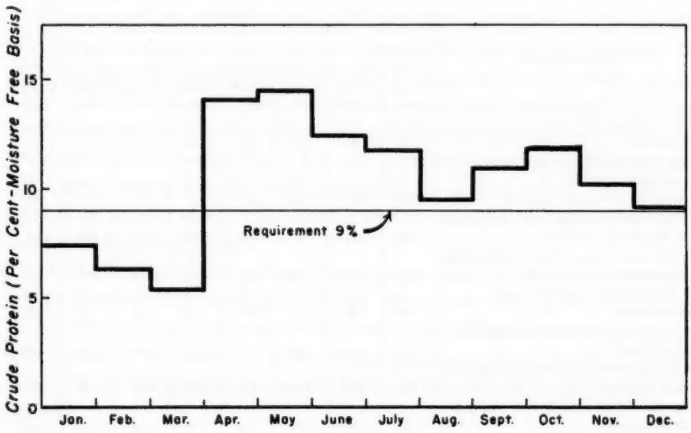

Figure 1. Crude protein content of samples representing forage grazed by cattle on native range in relation to the approximate amount required from maintenance of breeding cows and of growing animals.

two-pound group were a little lighter at the end of the feeding period than were those in the four-pound group. Two of the cows in the two-pound group died because of poor condition and weakness, indicating that two pounds of concentrates per day may not be enough to maintain thrifty condition.

For the following grazing period the cows (both nursing and dry) that had received only two pounds of concentrates per head daily gained more rapidly than did those that had received four pounds, so that by the end of the grazing season the cows in both groups averaged practically the same weight. This is not unusual, however, as it is in line with the results of numerous investigations dealing with pasture gains of steers as affected by their previous winter gains. There was also no appreciable difference in the weights of the calves in the two groups at the end of the grazing season.

Second Trial

The second feeding trial was started on December 18, 1942, with three groups of similar cows, fed at the rates of two, four, and six pounds per head daily until May 4, 1943 (table 1). Soybean oil meal (46 percent crude

TABLE 1. RESULTS OF THREE WINTERING TRIALS COMPARING VARIOUS AMOUNTS OF PROTEIN SUPPLEMENT FOR BEEF COWS ON FOREST RANGE

Items compared	Trial No. 1		Trial No. 2			Trial No. 3		
	Group I	Group II	Group I	Group II	Group III	Group I	Group II	Group III
Wintering Period[1]								
No. of cows	27	27	32	32	32	30	31	30
Amount of cottonseed meal or soybean oil meal daily, (pounds)	2	4	2	4	6	2	4	6
Average initial weight, (pounds)	776	776	730	730	730	752	753	753
Average loss for nursing cows during wintering period, (pounds)	−129	−94	−80	−69	−19	−212	−106	−91
Average gain or loss for dry cows during wintering period, (pounds)	−3	52	44	98	109	−36	−2	38
No. of cows died during winter	3	1	2	2	1	3	1	1
Percent calved	74	78	72	81	75	40	52	70
Avg. age of calves at close of winter period, (days)	57	47	58	56	64	50	42	47
Avg. weight of calves at close of winter period, (pounds)	106	116	119	124	155	107	108	110
Avg. gain of calves to close of winter period, (pounds)[3]	37	42	52	52	77	34	40	43
Following Grazing Season[2]								
Avg. gain for nursing cows during grazing season, (pounds)[4]	99	56	35	29	−2	121	56	85
Avg. gain for dry cows during grazing season, (pounds)	183	167	137	84	126	221	211	194
Percent of calves weaned (based on No. of cows bred)	63	74	63	75	69	33	52	67
Avg. age of calves at weaning, (days)[5]	249	234	231	220	221	212	202	213
Avg. weight of calves at weaning, (pounds)	296	298	276	281	311	285	268	275
Avg. weight of calves at weaning corrected for age, (pounds)[6]	292	301	270	284	314	281	277	270
Avg. gain of calves during grazing season, (pounds)	188	192	154	158	158	168	159	167
Avg. gain of calves for winter and grazing season, (pounds)	224	234	206	210	235	202	199	210

[1] The wintering period in the 3 trials were 1-15-42 to 5-8-42, 12-18-42 to 5-4-43, and 12-30-43 to 4-24-44.

[2] The following grazing seasons continued to 11-20-42, 10-22-43, and 10-10-44, respectively.

[3] From first weight after birth.

[4] Cows in the second trial made good gains during early part of grazing period, but season became dry, forage became scarce and cows had been losing weight since about August.

[5] A few calves were born and a few died in each trial after 5-8-42; 5-4-43, and 4-24-44, respectively.

[6] Corrections made using intra-group regression of weight on age.

protein) was used in this test because cottonseed meal could not be obtained. The cows used in the first trial were re-grouped so that an equal number were placed in each of the three new groups and bred three-year-old heifers were added to bring the total in each group to 32. All cows lost weight at calving, of course, but for the wintering period the cows in the four-pound group lost somewhat less than did those in the two-pound group, and those in the six-pound group practically maintained their weights. The dry cows in all groups made satisfactory gains that were about directly proportional to the amounts of protein concentrate eaten.

The time of calving and number of cows that calved were rather evenly distributed among the three groups. It should be pointed out here that the first feeding trial apparently produced no effect on the percentage of this year's calf crop because when calculations were made according to previous treatment, the cows in the two-pound group produced as many calves as did those in the four-pound group. The calf gains in the wintering period of this trial were nearly fifty per cent greater in the group where the cows received six pounds of soybean oil meal per head daily than were those in the two- or four-pound groups.

During the following summer the average gains of the cows were again about reversed from their gains during the winter. The gains of the calves in the three groups, however, were about equal. When the winter and summer gains of the calves are considered together, those in the six-pound group made the greatest gains and those in the two-pound group the least gains.

Third Trial

The third wintering trial was started on December 30, 1943, and was continued until April 24, 1944 (table 1). Three groups of 30 to 31 cows each were fed 41 percent crude protein cottonseed meal at the rates of two, four, and six pounds per head daily. To study the accumulative effects of feeding protein concentrates at different levels, the cows used in the preceding trial were kept in their same groups with the addition of three or four bred three-year-old heifers.

In the third trial the cows in all three groups calved without difficulty, but the percentage calf crop decreased from what it had been the two previous years. This reduction was considerably greater in the groups fed two pounds and four pounds than it was in the group receiving six pounds, and probably was due to the differences in amount of concentrates given the previous winter. Even though the cows that had been wintered on the lower amounts of supplements were, by more rapid summer gains, in nearly as good condition at the close of the preceding grazing season as were those in the six-pound group, many of them apparently were too poor at breeding time

to conceive. In the three groups combined there were 46 living calves which, instead of being rather evenly distributed among the groups, as was the case the first two years, were distributed 10 in the two-pound group, 16 in the four-pound group and 20 in the six-pound group. All cows that calved lost weight during the wintering period but the losses were much less in the groups receiving the most supplement. The dry cows made slight gains in the six-pound group practically maintained their weight in the four-pound group, and lost nearly 40 pounds per head in the two-pound group. The average gains of the calves from the first weigh day after birth until the close of the winter period were only slightly less in the two-pound group than in either of the other two groups. Again, more cows died in the two-pound group because of weakness and poor condition.

The summer gains for the cows in the third trial were again greater in the groups that had received the least amount of protein supplement the previous winter. However, there was very little difference in the gains of the calves.

The relationship between the winter losses and summer gains in weight of the cows in the different groups is shown in the graph in figure 2, which is an average of the nursing cows for the three trials.

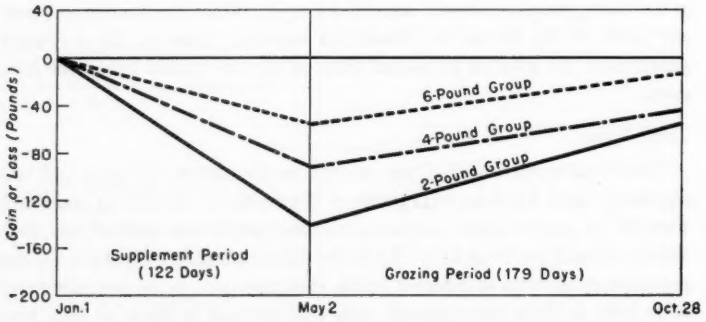

Figure 2. Average of three trials showing winter losses and summer gains of nursing cows on forest range supplemented with protein concentrates during the winter. From about May 2 to Oct. 28, when the calves are weaned, the groups are grazed together. After this date the cows are combined on a slightly above maintenance forest range until separated again for the supplemental feeding period. Calving occurred from about Feb. 1 to May 1.

Discussion of Three Trials

The weight changes of dry and nursing cows during the wintering period in all three trials were in proportion to the amount of supplement furnished.

The groups receiving the most supplement in all cases either lost less weight or gained more. The differences among the groups were highly significant statistically except for the nursing cows in 1942 and the dry cows in 1943, however, even in those instances the results conformed to the general pattern. The greatest drop in weight of the nursing cows occurred at calving. Before this time the changes in weight were similar to those of the dry cows, which were slight. All cows were in the poorest condition in March when the forage was scarce and of lowest quality, but most of them began gaining in April when new forage appeared. Although it was not definitely brought out in the experiment, the authors believe, based on observations and monthly cattle weights, that in commercial cattle operations it would be most practical to start feeding two pounds per head daily and increase this amount as the available forage and condition of the cattle warrant.

On the average, gains during the grazing season were inversely related to weight changes during the winter, *i.e.*, those groups that lost more or gained less in the winter gained the most weight during the grazing season. However, the cattle were also used in a grazing experiment during the summer, and while every effort was made to have the groups represented equally in all forest ranges, this could not be entirely accomplished. It is recognized that the data on summer gains are somewhat less reliable for that reason. This also prevented an exact statistical evaluation of the results.

Differences among the groups in average weaning weights of calves, corrected for age by the covariance technique, were statistically significant only in 1943 but it will be noted that the results in 1942 were in general agreement. The results of 1944 were probably due to the fact that the proportion of calves raised by cows dry the previous year were highest in the two-pound group and lowest in the six-pound group.

The regression of percent calf crop on amount of supplement furnished the previous winter was highly significant in the third trial. Apparently, condition during the breeding season was the controlling factor. It is anticipated that the comparative calving percentages in 1945 may differ considerably from 1944 when the proportion of dry cows was so much higher in the two- and four-pound groups than in the six-pound group.

Summary and Conclusions

Three tests have been made thus far on wintering beef cows on different amounts of protein concentrates on forest range in the Coastal Plain of North Carolina. Two levels were tested in the winter of 1941–42 and three levels were tested the next two years.

These studies are bringing out the practicability of wintering breeding cows on forest range in this area. Even though some of the cows were fed as

much as six pounds of cottonseed meal or soybean oil meal per head daily, they were wintered more economically than they could have been wintered on the farm at existing feed prices. Furthermore, grazing observations revealed no evidence of pines, which are the type of reforestation desired in that area, being browsed.

The studies have not gone far enough to determine the most economical amount to feed. There is a strong indication, however, that it might be most practical to start feeding two pounds per head daily and increase this amount as the available forage and the condition of the cattle warrant.

Most of the differences in gains of the groups of cows during the winter were offset the following summer by the greater gains of the cows that had received the least supplement the preceding winter. However, if the cows are wintered too poorly the death losses will be greater and the following calf crops may be materially reduced due to the cows being too poor to breed or conceive during the normal breeding season. A practical cattleman can guard against this by frequent inspections of the available forage in his range and the condition of his cattle. He can then increase the amount of protein concentrate whenever it is needed in order to maintain the proper condition in his cattle.

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THE COMPOSITION AND APPARENT DIGESTIBILITY OF BLUESTEM GRASS IN THE GROWING STAGE, AND IN THE DRY AND HAY STAGES WHEN SUPPLEMENTED WITH COTTONSEED CAKE

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EXTENSIVE use is made of native pasture grasses during the growing season to supply the total nutrient requirements of range beef cattle. The composition of these grasses on the western ranges varies widely depending on the predominant grass species and their stage of maturity, climate and soil conditions, and related factors (Watkins, 1943; Fudge and Fraps, 1944). In the bluestem area, bluestem and associated long-type grasses provide excellent forage for summer grazing. The high nutritive value of bluestem pastures has been demonstrated in numerous grazing trials (Taylor *et al.*, 1944). Changes in the composition of the grass are largely seasonal and occur most rapidly in spring and late summer. The dry winter grass is notably low in protein.

A series of digestion trials was conducted with steers in 1942 to determine the digestible nutrient content of typical native pasture grass, mostly bluestem, during successive periods of the grazing season. Since cattle are frequently kept on pasture and given a protein supplement during the winter months, the trials were continued during the winter and early spring to determine the apparent digestibility of rations of the dry winter grass and of the cured grass, designated as prairie hay, supplemented with cottonseed cake. This paper reports the results of these studies.

Experimental Material and Method

Four yearling Hereford steers which had been used in a winter feeding trial in 1941–42 were selected for this work. Their individual weights at the beginning of the grazing season varied from 520 to 630 pounds.

The pasture which was grazed by the steers and from which the grass was cut for digestion trials consisted of 13 acres of native grass made up of approximately 52 percent Little Bluestem, 11 percent Big Bluestem, 2 percent Side-oats Grama, 1 percent Blue Grama, 27 percent of other less common grasses and 7 percent weeds. This pasture had been used as a meadow for several years. It contained 93 percent grass and had a grass density of 16.3 percent.

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Six digestion trials in which the steers received grass alone were conducted between June 15 and November 15. In the first and last trials of this period the four steers were kept in dry lot and individually fed daily cuttings of grass from the pasture. In the four intervening trials, two steers were similarly fed in dry lot and two were allowed to graze the pasture. The dry-matter intake of the two steers on pasture was calculated from the amount of their dry-matter defecation according to the method proposed by Garrigus and Rusk (1939) and employed by Crampton and Purdy (1941). By this procedure the dry-matter consumption: defecation ratio of an individual steer was established during a digestion-trial conducted in dry lot. This ratio was used to determine the grass consumption of the same steer during a subsequent period on pasture. Feces collections were made from the steers on pasture and those in dry lot by means of special feces-collector sacks (Garrigus and Rusk, 1939). All the steers were allowed to graze the pasture between trials.

Daily cuttings of grass were made with a mowing machine in the late afternoon. The grass was brought to the feeding shed where the required amounts for a night and morning feeding were weighed out for each steer being fed in dry lot. At the same time, duplicate samples were taken for determinations of dry matter and chemical composition. The steers on pasture and in dry lot had access to water and a mineral mixture of bone meal, limestone, and salt at all times. In the dry-lot trials refused feed was collected daily, weighed, and the dry matter determined. In the pasture trials, the dry-matter intake of the steers was determined as described above.

The feces sacks were changed twice daily at which times 1/20th aliquots of feces were preserved with thymol in gallon glass jars in an electric refrigerator. In general, preliminary periods were of 10 days duration and feces collecting periods of 8 or 9 days duration. Proximate chemical analyses (A. O. A. C., 1940) were made at the close of each trial on composite aliquoted samples of feed offered, refused feed, and the feces. The nitrogen of the feces was determined previous to drying.

After November 15 all the steers were kept in dry lot and fed cottonseed cake as a supplement to dry grass which was cut from the pasture about every two weeks. In one digestion trial all the steers received 2 pounds of cottonseed cake daily. In two succeeding trials, the group was divided and two steers continued on this ration while the remaining two steers were given 3 pounds of cake daily. This division was maintained in two subsequent trials when the steers were fed prairie hay and either 2 or 3 pounds of cottonseed cake.

Results

The composition of native grass, predominantly bluestem, cut at intervals

during the grazing season and winter of 1942–43 is given in table 1. The summer grass which was cut between May 18 and September 14 showed a general decrease in protein and in ether-extract with advance in season. The nine samples of grass cut late in June and used in the first digestion trial showed a marked drop in protein for which there is no explanation. The samples which were taken during July, August, and September and used in digestion trials 2, 3, and 4 were especially uniform in composition, their average content of protein and crude fiber being 7.75 percent and 31.24 percent

TABLE 1. AVERAGE COMPOSITION OF NATIVE PASTURE GRASS CUT AT INTERVALS DURING 1942 AND 1943, AND OF PRAIRIE HAY AND COTTONSEED CAKE USED IN DIGESTION TRIALS

Description	Date of first cutting	Samples[1]	Dry matter	Composition of dry matter					Digestion trial no.
				Ash	Protein	Ether extract	Crude fiber	N-free extract	
		number	*percent*	*percent*	*percent*	*percent*	*percent*	*percent*	
Native grass	May 18, '42	2	32.7	7.95	8.97	2.79	29.03	51.25	
" "	June 13, '42	7	34.8	7.15	8.36	3.10	30.41	50.98	
" "	June 21, '42	4	38.0	7.26	7.53	2.94	28.46	53.81	
" "	June 25, '42	9	38.5	7.10	6.77	3.05	30.48	52.60	1
" "	July 17, '42	9	39.0	7.55	7.90	2.64	30.54	51.37	2
" "	Aug. 15, '42	5	37.8	7.65	7.60	1.53	31.60	51.62	
" "	Aug. 23, '42	9	35.9	7.66	7.57	1.70	32.32	50.75	3
" "	Sept. 6, '42	8	38.2	8.32	7.78	1.85	30.86	51.19	4
" "	Oct. 21, '42	8	67.5	9.20	4.31	1.68	33.99	50.82	5
" "	Nov. 6, '42	8	79.5	9.06	3.86	1.69	33.40	51.99	6
" "	Dec. 12, '42	8	87.1	9.53	3.35	2.04	33.89	51.19	7
" "	Jan. 19, '43	8	88.7	8.97	3.48	1.80	32.97	52.78	8
" "	Feb. 18, '43	8	86.5	8.11	2.56	1.19	32.04	56.10	9
Prairie hay	August '42	2	93.05	7.38	4.20	1.75	34.77	51.90	10, 11
Cottonseed cake		5	93.81	6.49	45.65	7.20	8.72	31.94	7, 8, 9, 10, 11.

[1] Samples were cut from the pasture on consecutive days except after November when sufficient grass was cut at one time to complete a digestion trial. Daily samples were taken from these large cuttings during each digestion trial.

respectively. The greatest change in the grass occurred between September 14 and October 21. The grass became dry about this time and its protein content dropped to 4.31 percent while the crude fiber content increased to approximately 34 percent. The protein content of the grass continued to decrease during the next four months until in February it reached the low value of 2.56 percent. Changes in other constituents of the grass were small and irregular.

The cottonseed cake used in the last five digestion trials and the prairie hay were of average composition.

The individual and average results of the digestion trials in which the

TABLE 2. APPARENT DIGESTIBILITY OF NATIVE PASTURE GRASS CUT AT INTERVALS DURING THE SUMMER AND FALL OF 1942

Trial no.	Month	Protein content of grass (dry basis)	Steer no.	Period	Daily grass intake (dry basis)	Apparent digestibility of :					Fecal N / Dry matter intake ×100
						Dry matter	Protein	Ether extract	Crude fiber	N-free extract	
		percent			*grams*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	
1	June	6.77	1	Dry lot	3222	54.8	37.7	48.4	62.5	62.4	0.73
			2	" "	2606	52.9	31.7	45.4	61.9	60.3	0.67
			3	" "	4247	56.9	41.5	45.1	65.3	62.6	0.63
			4	" "	3638	57.6	42.8	45.3	67.1	63.9	0.61
	Average				3428	55.5	38.4	46.1	64.2	62.3	0.66
2	July	7.90	1	Dry lot	4991	61.0	55.0	39.0	69.5	65.5	0.57
			2[1]	Pasture	4473	52.9	37.9	19.2	65.9	62.1	0.78
			3	Dry lot	5389	58.2	48.3	38.2	71.0	60.7	0.66
			4[1]	Pasture	5396	57.6	41.5	23.0	72.3	63.7	0.74
	Average				5062	57.4	45.7	29.8	69.6	63.0	0.69
	Average of 1 and 3				5190	59.6	51.6	38.6	70.2	63.1	0.61
3	August	7.57	1	Dry lot	4326	58.1	45.2	17.4	70.5	61.6	0.67
			3	" "	5211	58.3	44.7	7.4	72.2	61.0	0.68
			4[2]	Pasture	5303	55.8	38.8	1.0	72.5	59.6	0.74
	Average				4946	57.4	42.9	8.6	71.7	60.7	0.70
	Average of 1 and 3				4768	58.2	44.9	12.4	71.3	61.3	0.68
4	September	7.78	1	Dry lot	6162	59.9	56.4	29.4	70.4	62.1	0.55
			3[3]	Pasture	6789	58.3	42.0	10.1	70.1	63.7	0.72
			4	Dry lot	5602	55.8	51.1	21.0	68.0	60.1	0.62
	Average				6184	58.0	49.8	20.2	69.5	63.0	0.63
	Average of 1 and 4				5882	57.9	53.7	25.2	69.2	61.1	0.58
5	October	4.31	1[4]	Pasture	6512	42.4	−12.9	−13.9	62.7	46.2	0.78
			2[4]	"	4772	36.2	−31.6	−33.4	58.5	42.2	0.91
			3[4]	"	5130	39.2	−20.8	−25.0	60.8	43.1	0.83
			4[4]	"	6624	46.1	− 6.5	−12.9	65.0	49.4	0.74
	Average				5759	41.0	−17.9	−21.3	61.7	45.2	0.81
6	November	3.86	1	Dry lot	3656	42.4	− 8.7	27.2	62.6	42.1	0.67
			2	" "	3487	36.2	−15.7	23.0	58.6	34.1	0.71
			3	" "	3321	39.2	−30.5	28.4	60.1	40.3	0.75
			4	" "	3671	46.1	−10.3	29.3	65.1	47.1	0.65
	Average				3533	41.0	−16.3	27.0	61.6	40.9	0.70

[1] Grass intake calculated from dry-matter consumption: defecation ratio of trial 1.
[2] Grass intake calculated from dry-matter consumption: defecation ratio of trial 4.
[3] Grass intake calculated from dry-matter consumption: defecation ratio of trial 3.
[4] Grass intake calculated from dry-matter consumption: defecation ratio of trial 6.

steers received grass alone are given in table 2. In June the apparent digestibility of the protein and crude fiber of the grass was low. The low value for protein digestibility, 38.4 percent, can be explained by the relatively low protein content of the grass. The low value for crude fiber digestibility, 64.2 percent, is at variance with the usual observation that the crude fiber of early grass is highly digestible. It is possible that the character of the constituents making up the N-free extract of the grass during June adversely affected the digestibility of crude fiber (Mitchell, 1942). The digestibility of ether-soluble constituents, 46.1 percent, was high during this month.

During July, August, and September the digestibility of dry matter, crude fiber and N-free extract varied only slightly. The most important change in the digestibility of the grass occurred after September when dry-matter digestibility decreased from about 58 percent to 41 percent. The apparent digestibility of crude fiber and N-free extract decreased in a like manner to 61.6 percent and 40.9 percent, respectively, while the digestibility coefficients for protein became negative. The initial change in digestibility evident in the November trials and indicated in the calculated values of the October trials probably occurred in October at the time of maximum change in the composition of the grass. In October and November only dry grass was available to the steers. The dry-matter intakes of the steers on pasture during October were calculated from the dry-matter consumption: defecation ratios determined for each steer in November. The steers were in dry lot in November and individually fed known amounts of dry grass cut from the pasture. The calculated digestibility coefficients for protein and ether extract of the October grass are probably low; their significance is discussed in another part of this paper.

The results of the digestion trials with dry winter grass and prairie hay rations are presented in table 3. A decrease in the apparent digestibility of dry matter, protein, and crude fiber in the late winter grass is shown by a comparison of the results of trial 7 with those obtained with steers 1 and 3 receiving the same amount of protein supplement in trials 8 and 9. Dry-matter digestibility decreased from 45.2 percent in the December grass ration (trial 7) to 40.8 per cent in the February grass ration (trial 9), while protein digestibility decreased from 52.1 percent to 44.7 percent and crude fiber digestibility decreased from 60.5 percent to 50.4 percent. Similar decreases are shown when the results obtained with steers 2 and 4 in trial 8 are compared with those obtained with the same steers in trial 9. An increase in the apparent digestibility of all nutrients, attributed to the additional amount of cottonseed cake in the ration is indicated by the high values obtained with steers 2 and 4 in trials 8, 9, 10, and 11; a single exception is the low digestibility of crude fiber in period 9.

Roughage intake was greatly increased when the steers were changed from winter grass to hay rations. A comparison of the results obtained in trials 10 and 11 indicate that the total dry matter of the hay was more digestible than that of the January and February grass.

Discussion

The data in table 2 show some characteristic differences between digestibility coefficients determined by the two procedures employed. The apparent digestion coefficients of protein and ether-extract obtained with steers on pasture were generally low as shown by comparison with corresponding

TABLE 3. APPARENT DIGESTIBILITY OF RATIONS OF DRY WINTER GRASS AND PRAIRIE HAY SUPPLEMENTED WITH COTTONSEED CAKE

Trial no.	Month	Steer no.	Roughage		Average daily cotton-seed cake intake (dry basis)	Average protein content of ration (dry basis)	Apparent digestibility of				
			Description	Average daily intake (dry basis)			Dry matter	Protein	Ether extract	Crude fiber	N-free extract
				gm.	gm.	percent	per cent	per cent	per cent	per cent	per cent
7	December	1,2,3,4	Grass	3568	854	11.26	45.2	52.1	62.5	60.5	41.2
8	January	1,3	"	3722	854	11.07	41.1	51.7	61.1	53.5	38.8
8	"	2,4	"	3608	1281	14.40	45.9	60.3	71.8	55.8	42.7
9	February	1,3	"	3916	856	10.23	40.8	43.7	61.7	50.4	41.3
9	"	2,4	"	3260	1284	14.43	44.1	56.9	71.8	44.3	45.9
10,11	April	1,3,1,3	Prairie hay	5498	854	10.03	44.0	44.5	56.6	56.5	43.7
10,11	"	2,4,2,4	" "	5004	1268	12.78	46.3	53.6	62.5	58.3	45.0

values obtained with steers in dry lot during the same period or with the same steers during subsequent dry-lot periods. These low values indicate that the fecal excretion of nitrogen and ether-soluble material, possibly of metabolic origin, is increased when steers are grazing on pasture. Fictitiously low feed-intake values calculated for the steers on pasture would likewise account for these low coefficients but would produce correspondingly low values for crude fiber and N-free extract. On the contrary, crude fiber values were consistently in close agreement wherever comparisons were permissible.

An alternate explanation might be that the steers on pasture consumed grass of considerable higher protein and ether-extract content than that cut from the pasture for analysis and dry-lot digestion trials. There was some

opportunity for this to occur when the pastures were dry in October and November, at which time the animals on pasture in trial 5 gave exceptionally low (negative) values for the apparent digestibility of protein and ether-extract. A small positive value for protein digestibility in trial 5 was anticipated since the grass contained over 4 percent protein. An increased excretion of fecal metabolic nitrogen, however, would account for the negative value obtained and would not affect the values obtained for other nutrients which, with the exception of ether extract, showed good agreement between trials 5 and 6.

Further evidence that fecal-nitrogen excretion is increased when steers are on pasture was obtained by calculating the amount of fecal nitrogen per 100 grams of dry-matter intake for each steer during different periods. A comparison of these values presented in the last column of table 2 shows that nitrogen excretion on this basis was always high during pasture periods. This holds true for the different steers during the same trial and the same steers in adjacent trials. The average value was 0.66 during dry-lot periods and 0.78 during pasture periods. The similarity of values obtained with steers in dry lot when known amounts of grass of varying protein content were fed is in agreement with the conception that the fecal-nitrogen excretion of ruminants is more closely related to their dry-matter intake than to the protein content of the ration (Mitchell, 1942*a*).

Summary

The composition of native pasture grass, predominantly bluestem, being grazed by steers was determined at frequent intervals during the grazing season and winter of 1942–43. From late in May until the middle of September the dry matter of the grass varied from 32.7 percent to 39.0 percent. The composition of the dry matter during those months varied from 6.77 percent to 8.97 percent in protein and from 28.46 percent to 32.32 percent in crude fiber. After September protein decreased to 4.31 percent and crude fiber increased to about 34 percent. Further decrease of protein to 2.56 percent without a corresponding increase in crude fiber took place during the winter. Variations in N-free extract were small and irregular throughout the summer and winter.

The digestibility of the grass was determined during periods when the steers were individually fed in dry lot and during periods when they were allowed to graze the pasture. Grass intake during the grazing periods was calculated from the dry-matter consumption:defecation ratios determined for each steer during dry lot periods which either preceded or immediately followed the grazing periods.

The apparent digestibility of dry matter, protein, and crude fiber of the

grass was lower in June than in July, August and September. During the latter months there was practically no change in the digestibility of the nutrients, with the exception of protein and ether extract. The apparent digestibility of dry matter, protein, crude fiber, and N-free extract decreased from about 58 percent, 54 percent, 69 percent, and 61 percent, respectively, in September, to about 41 percent, −16 percent, 62 percent, and 41 percent, respectively, in November.

The digestibility of the dry winter grass was somewhat higher in December than in January and February. Supplements of cottonseed cake improved the digestibility of both winter grass and prairie hay rations. The dry matter of the late winter grass was less digestible than that of cured hay.

Digestion trials conducted during grazing periods gave some evidence that the fecal excretion of nitrogen and ether-soluble material is greater in steers on pasture than in steers in dry lot.

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A COMPARISON OF DIFFERENT PHOSPHATE SUPPLEMENTS FOR HOGS AND RATS[1]

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INADEQUATE supplies of bone meal and other phosphates suitable for animal feeding have emphasized the importance of finding additional sources of phosphorus. Defluorinated phosphates would seem to have some promise for use in livestock rations. The present study includes observations on the relative value of steamed bone meal, defluorinated phosphate,[5] rock phosphate and superphosphate as mineral supplements for growing and reproducing swine, and experiments with these and additional phosphorus compounds for growing and breeding rats.

Considerable published work shows the effect of the fluorine and the form of phosphorus in rations in producing abnormal metabolism of calcium and phosphorus in animals. These experiments have been reviewed by Mitchell and McClure (1937) and by Mitchell (1942, 1943). Barrentine, Maynard, and Loosli (1944) reported that the low availability of samples of defluorinated superphosphates for the rat might be due to the presence of calcium metaphosphate.

Experimental

Three experiments with growing pigs and one with breeding swine are described. The ration fed to the pigs was 87.5 parts of ground yellow corn and 12.5 parts of soybean oil meal plus the amounts of the minerals required to bring the phosphorus content of the ration to 0.43 percent. Pulverized limestone was added to produce a calcium to phosphorus ratio of 1.5. The basal ration for the breeding stock was 58.3 parts ground yellow corn, 29.2 parts ground oats, 12.5 parts soybean oil meal plus the calculated amounts of mineral supplements. All rations contained 0.1 percent of common salt and in addition block salt was supplied in all lots. The swine were quartered in dry lots paved with concrete. Similar rations were fed to rats which were kept in individual cages in a temperature controlled room. Femurs from the pigs and rats were secured for measurement and analyses.

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[5] The defluorinated phosphate used was manufactured during early production of the material and may not be representative of the defluorinated phosphate now on the market.

Results

The three experiments with growing pigs are described in table 1. In the first experiment, pigs weighing approximately 100 pounds were used. They were fed for 83 days and finished in the experiment with an average weight of about 240 pounds. Although the fluorine content of the rations

TABLE 1. THE VALUE OF DIFFERENT PHOSPHORUS SUPPLEMENTS FOR GROWING PIGS

(10 pigs fed in each lot)

Lot No.	Mineral****	Fluorine in mineral	Fluorine in ration	Avg. initial weight of pigs	Avg. final weight of hogs	Avg. total gain	Avg. daily gain	Avg. total feed	Feed required per 100 lbs. gain
		First experiment							
		percent	*percent*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*	*pounds*
1	Steamed bone meal	0.02	0.0005	100.3	239.2	138.9	1.67	535	385
2	Defluorinated phosphate	0.06	0.0006	99.1	238.9	139.8	1.68	552	395
3	Rock phosphate	3.75	0.0291	98.6	238.2	139.6	1.68	533	382
4	Superphosphate	1.78	0.0243	100.1	241.5	141.4	1.70	608	430
	LSMD—5* P=.05*					13.5			
	1 P=.01					18.1			
		Second experiment							
1	Steamed bone meal	0.06	0.0009	41.9	225.8	183.9	1.56	684	372
2	Defluorinated phosphate	0.03	0.0006	50.2	227.1	176.9	1.50	690	390
3	Rock phosphate	3.90	0.0306	45.4	214.2	168.8**	1.43	635	376
4	Superphosphate	1.53	0.0227	48.6	234.7	186.1	1.68	686	368
	LSMD—5* P=.05*					12.8			
	1 P=.01					17.1			
		Third experiment							
1	Steamed bone meal	0.05	0.0006	45.6	256.9	211.3	1.50	916	434
2	Defluorinated phosphate	0.04	0.0005	41.8	233.9	192.1***	1.36	881	458.
3	Rock phosphate	3.40	0.0262	30.3	213.4	183.1***	1.30	788	430
4	Superphosphate	1.65	0.0248	42.7	239.9	197.2**	1.40	855	434
	LSMD—5* P=.05*					9.3			
	1 P=.01					12.5			

* LSMD = Least significant mean difference.

** Significantly different from control lot 1 (steamed bone meal) at 5% level.

*** Significantly different from control lot 1 (steamed bone meal) at 1% level.

**** All mineral mixtures contained limestone to adjust the calcium to phosphorus ratio of the ration to 1.5.

varied from 0.0005 to 0.0291 percent, no important difference in rate of gain was observed. The feed required to produce 100 pounds of gain was similar in all lots, except the one fed superphosphate (lot 4) which required the most feed. However, in the second experiment where pigs weighing 40–50

pounds at the start were used, there was considerable difference in the rate of gain. The pigs in this experiment were from gilts selected from the first growth experiment. Those receiving defluorinated phosphate or rock phosphate grew at slower rates than those fed steamed bone meal or superphosphate. The reduction in gain was statistically significant only in the case of rock phosphate. Feed consumption for 100 pounds of gain was higher for pigs fed defluorinated phosphate than for those in the other lots. In the third experiment, which also utilized light-weight pigs and which had the longest feeding period (141 days) results similar to those in experiment 2 were obtained. These pigs were from the second litter of the sows that had been fed the different minerals from the time they weighed 100 pounds. Here again defluorinated phosphate and rock phosphate caused a reduction in rate of gain as compared to the steamed bone meal with the greater reduction in the lot fed rock phosphate. In both cases however, the differences were statistically significant. Superphosphate which produced growth in pigs equal to that with steamed bone meal in experiments 1 and 2 was not so efficient in the third experiment. As was the case in the first and second experiments, feed efficiency was lowered in the lot fed defluorinated phosphate.

The results of the bone studies show that defluorinated phosphate and rock phosphate were not equal to steamed bone meal and superphosphate in producing high quality bone (table 2). The percentage of fluorine in the bone, which ranged from 0.04 to 0.61 percent, increased somewhat in proportion to the percentage of fluorine in the raotin (0.0005–0.0306). Although fluorine was deposited in the bone in large amounts from rations containing high levels, a lower percentage of the total dietary fluorine was deposited than from rations containing lower levels. This suggests that a saturation or threshold level is reached, beyond which storage is reduced. Fluorine storage in the bone was not related significantly to either the percentage of ash, length, diameter, wall thickness or weight of the bone. However, trends were observed, since the lot receiving defluorinated phosphate (lot 2) produced bones of the lowest ash, the lowest weight, with one exception (lot 3, experiment 3), and the least wall thickness. The breaking strength of the bone was not proportional to the fluorine content as might be expected. While steamed bone meal produced bones with relatively high breaking strength and low fluorine content in all three experiments, defluorinated phosphate produced bones with low breaking strength, although the fluorine content was also low. Conversely rock phosphate produced bones of relatively high breaking strength, although the fluorine content was consistently high. The same was true of superphosphate.

Five gilts were selected from each of the four lots in growth experiment No. 1 for reproduction studies. Since plain salt was used in the rations at this

time, iodine deficiency developed, as shown by the production of hairless pigs, and complicated the results to the extent that any effect of the minerals could not be determined.

TABLE 2. THE EFFECT OF DIFFERENT PHOSPHORUS SUPPLEMENTS ON THE CHARACTER OF BONES OF PIGS[1]

(10 pigs fed in each lot)

Lot No.	Mineral[2]	Fluorine in mineral	Fluorine in ration	Avg. length of bone	Avg. diameter of bone	Avg. wall thickness of bone	Avg. breaking strength of bone	Avg. green bone weight	Avg. ash in bone	Avg. fluorine content of bone
	First experiment									
		per cent	*per cent*	*inches*	*inches*	*inches*	*pounds*	*grams*	*per cent*	*per cent*
1	Steamed bone meal	0.02	0.0005	7.76	0.893	0.214	1082	177	59.0	0.15
2	Defluorinated phosphate	0.06	0.0006	7.60	0.890	0.152	759**	165	57.2	0.18
3	Rock phosphate	3.75	0.0291	7.59	0.927	0.165	920	182	58.8	0.61***
4	Superphosphate	1.78	0.0243	7.66	0.898	0.162	807**	173	59.6	0.59***
	LSMD P=.05*						244			0.33
	P=.01						332			0.46
	Second experiment									
1	Steamed bone meal	0.06	0.0009	7.39	0.820	0.191	1051	235	60.5	0.04
2	Defluorinated phosphate	0.03	0.0006	7.34	0.799	0.168	915	215	59.4	0.08
3	Rock phosphate	3.90	0.0306	7.09	0.843	0.206	991	216	61.5	0.55***
4	Superphosphate	1.53	0.0227	7.40	0.905	0.208	1153	243	61.2	0.49***
	LSMD P=.05*						224			0.08
	P=.01						360			0.11
	Third experiment									
1	Steamed bone meal	0.05	0.0006	7.70	0.897	0.172	994	260	60.3	0.14
2	Defluorinated phosphate	0.04	0.0005	7.38	0.886	0.147	816	225	57.6	0.08**
3	Rock phosphate	3.40	0.0262	6.88	0.875	0.219	1166	201	60.8	0.60***
4	Superphosphate	1.65	0.0248	7.25	0.926	0.172	1037	231	59.9	0.47***
	LSMD P=.05*						350			0.04
	P=.01						478			0.06

[1] 1st experimental period 83 days; 2nd 118 days; 3rd experiment 141 days.

[2] All mineral mixtures contained limestone to adjust the calcium to phosphorus ratio of the ration to 1.5. Phosphorus content of all rations 0.43 percent. Fluorine content of limestone =0.02, 0.0 to 0.05.

* LSMD =Least significant mean difference.

** Significantly different from control lot 1 (steamed bone meal) at 5% level.

*** Significantly different from control lot 1 (steamed bone meal) at 1% level.

The experiment was repeated with iodized salt. Five gilts from each of the first three lots of growth experiment No. 3 were used. Since their dams had been fed the respective mineral supplements for a period of 16 months, and the gilts were fed the same supplements during their entire 18 months of life prior to farrowing, an opportunity for cumulative effects was provided.

The data (table 3) show that defluorinated phosphate was inferior to steamed bone meal with respect to the average number of pigs farrowed, birth weight of pigs, and percentage of strong pigs. Rock phosphate was comparable to steamed bone meal in the number and weight of pigs farrowed but inferior to both steamed bone meal and defluorinated phosphate in strength of pigs at birth and the number stillborn.

The gilts were continued on the rations in dry lot until they farrowed again in six months. Steamed bone meal again produced the largest litters with the birth weight of the pigs essentially the same as in the other lots. However, the percentages of strong and stillborn pigs show opposite trends from the gilt data.

TABLE 3. REPRODUCTION RECORD OF GILTS AND SOWS FED DIFFERENT MINERAL SUPPLEMENTS

Lot No.	Mineral	No. of sows bred	No. of sows farrowed	Avg. No. of pigs per litter	Avg. birth weight of pigs (pounds)	Percentage of strong pigs	Percentage of pigs born dead
			*Gilts**				
1	Steamed bone meal	5	4	11.25	2.77	62.2	4.5
2	Defluorinated phosphate	5	5	9.60	2.57	56.3	6.3
3	Rock phosphate	5	5	11.00	2.62	38.2	12.7
			*Sows***				
1	Steamed bone meal	5	4	10.75	2.93	72.1	16.3
2	Defluorinated phosphate	5	5	8.40	2.91	78.6	7.1
3	Rock phosphate	5	4	7.50	2.98	90.0	0.0

* Five gilts from each of three lots in growth experiment 3 were selected for the reproduction tests. These gilts were 18 months old at farrowing time.

** The gilts that farrowed above rebred.

In the rat experiments an additional sample of defluorinated phosphate and a sample of metaphosphate were tested besides the mineral supplements used in the hog experiments. Growth, feed consumption, bone ash, and calcium and phosphorus retention were measured. Six male and 9 female rats were used in each lot. The results of the mineral retention studies were calculated on the basis of the amount of calcium and phosphorus ingested in the ration less the amounts excreted in the urine and feces. The results are presented in table 4. Growth rate and feed efficiency were inferior on defluorinated phosphate sample A (lot 2), rock phosphate (lot 4) and metaphosphate (lot 6) as compared to the steamed bone meal (lot 1). Defluorinated phosphate sample B (lot 3) and superphosphate (lot 5) were equal to the bone meal.

No significant differences were obtained in bone ash of the rats on the different mineral supplements. Calcium retention was considerably reduced on both samples of defluorinated phosphate as compared to steamed bone meal but not as much as in the case of rock phosphate, superphosphate, and metaphosphate. Phosphorus retention was reduced in the lot receiving defluorinated phosphate sample A (lot 2) but not with sample B (lot 3). Here again the retention of phosphorus was greater than in the case of rock phosphate, superphosphate, and metaphosphate. The fluorine content of the bones was proportional to the amount in the ration.

TABLE 4. THE EFFECT OF DIFFERENT MINERAL SUPPLEMENTS ON GROWTH, BONE DEVELOPMENT AND MINERAL STORAGE OF RATS*

Lot No.	Mineral supplement**	Fluorine content of ration	Total Avg. gain, 13 wks.	Feed per gram gain	Av. ash in bone	Calcium retention	Phosphorus retention	Fluorine in ash of bone
		percent	*grams*	*grams*	*percent*	*percent*	*percent*	*percent*
1	Steamed bone meal	0.00097	158.0	5.8	67.9	41.5	29.1	0.133
2	Defluorinated phosphate A	0.00073	148.0	6.1	67.6	38.7	24.5	0.099
3	Defluorinated phosphate B	0.00066	157.6	6.0	67.8	35.7	30.7	0.158
4	Rock phosphate	0.03257	130.8	6.6	68.9	28.6	16.6	0.666
5	Superphosphate	0.0227	161.4	5.8	68.9	24.5	12.3	0.514
6	Metaphosphate	0.00336	141.7	6.3	67.1	25.1	22.1	0.143

* 6 male and 9 female rats in each lot.

** Limestone or calcium carbonate added to mineral mixtures to adjust the calcium to phosphorus ratio to 1.8. Phosphorus content of ration 0.47 percent, calcium 0.75 percent.

The results show that both fluorine content of the ration and the form of phosphorus in the mineral were related to calcium and phosphorus utilization in the rat but that the form of phosphorus affected growth more than the fluorine content.

The four minerals used in the swine reproduction studies were also tested with rats. Approximately the same number of litters was produced by the rats in each lot and the average number of young in each litter was also similar. A larger percentage of young animals were weaned by rats fed rock phosphate and superphosphate than by those fed steamed bone meal and defluorinated phosphate. Differences in the average weight of the young at the time of weaning (21 days) were not large except in the case of superphosphate where the young were definitely heavier. The minerals did not materially affect reproduction in the rats.

Conclusions

1. In rations for growing pigs steamed bone meal was superior to either defluorinated phosphate or rock phosphate as a mineral supplement. Superphosphate compared favorably with steamed bone meal. The results were usually not related to the fluorine content of the ration.

2. In rations for bred sows and gilts steamed bone meal was only slightly superior to defluorinated phosphate and rock phosphate.

3. In studies with rats calcium and phosphorus retention was influenced by the fluorine content of the ration and the form of phosphorus in the mineral. Growth was affected more by the form of phosphorus than by the fluorine content of the ration. The various minerals studied had similar effects on reproduction.

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EFFECT OF DIET ON GESTATION-LACTATION PERFORMANCE OF SOWS

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THE object of these studies was to observe the effect of certian rations upon the gestation and lactation performance of sows that had been continuously in drylot from birth. Alfalfa meal and dried corn distillers' solubles were fed as natural carriers of the B_2-complex for gestation-lactation. The crystalline B-vitamins known to be required by the pig were also fed. Another objective was to study the residual effect of adequate nutrition during growth and gestation upon subsequent lactation when the sows were fed an inadequate ration while nursing their litters.

Experiments conducted at the Illinois Station (Fairbanks *et al.*, 1944; Krider *et al.*, 1944) showed that the fortification of certain rations with dried corn distillers' solubles, either for pigs in the creep or for lactating sows in drylot, did not increase weaning weights of the pigs. Nevertheless the higher nutritive state was manifested during the post-weaning period. Also these studies demonstrated the inadequacy for growing-fattening of certain rations composed of natural ingredients formulated to be adequate in protein, minerals, energy and vitamins A and D. The importance of the B_2-complex supplements was emphasized.

The inadequacy of certain rations composed of commonly used ingredients for gestation and lactation has been studied and reported by several workers (Fishwick, 1932; Cunha *et al.*, 1944; Aubel, Hughes and Lienhardt, 1929, 1932; Hogan, 1932, 1932 (*a*); Hogan and Johnson, 1933, 1935, 1940; Hogan, Johnson and Gahley, 1938; Hogan and McRoberts, 1940; Ross, Phillips and Bohstedt, 1942; 1942 (a); and Ross, *et al.*, 1944). A study of certain of these data indicates that the incorporation of 15 to 25 percent of alfalfa meal in the diets increased the percentage of the pigs weaned, but the weights at weaning were not always as heavy as desired. Wisconsin workers have emphasized the value of alfalfa meal as a carrier of the B_2-factors. At the Michigan Station (Gardner, 1932; Freeman, 1938), alfalfa hay was as efficient as tankage in supplementing corn for sows using weight, strength and number of pigs farrowed as measurements.

In his studies of the calcium requirements of brood sows, Hogan (1932) succeeded in raising to weaning age 81 percent of the pigs from sows whose

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gestation ration had contained 15 percent of alfalfa meal, whereas sows whose ration had contained only 5 percent of alfalfa meal weaned only 51 percent of their pigs. A later report (Hogan and Johnson, 1941) showed that 76 percent of all pigs farrowed were weaned when sufficient quantities of alfalfa meal were added to a ration that had produced unsatisfactory results. Mortality of pigs was less when a combination of 25 percent alfalfa meal and 25 percent wheat by-products was fed in the ration.

The importance of pastures in supplying factors needed for optimum performance during lactation and for reducing baby pig mortality has been demonstrated (Hogan and Johnson, 1935; Aubel, Hughes and Lienhardt, 1932; and others). Mortality of pigs was found to be nearly twice as great in spring farrowings as in fall farrowings in the studies of Asdell and Willman (1941). This result was probably due in part to the fact that pastures were more commonly used in summer gestation and drylot feeding was more common during winter gestation. Most of the studies indicate that nutrition is one of the most important factors affecting death losses among young pigs.

Experimental Procedure

In the first experiment gilts from the test reported by Krider, Fairbanks and Carroll (1944) were retained for the gestation-lactation study when they reached 225 pounds in weight. During gestation the gilts were continued in drylot and on the same rations they had been fed during the growing-fattening phase of the experiments. The performance of the sows at farrowing time and the growth and survival of the pigs during the lactation period were used as a measure of the relative nutritive values of the rations.

In order to test the effect of gestation rations and their effect on lactation, the treatment should be standardized during lactation. This was accomplished by feeding all groups the basal ration listed below from farrowing to weaning with the exception of part of the gilts in the first experiment which were continued on the diets containing either 6 or 12 percent dried corn distillers' solubles. About seven to ten days before farrowing time each gilt was placed in an individual pen that had been cleaned thoroughly and disinfected. Guard rails and electric pig brooders were in each pen. Shavings were used for bedding.

The sows were hand-fed enough feed daily during gestation to keep them in thrifty condition but not too fat. During lactation each sow and litter was full fed, either by hand-feeding or self-feeding.

To prevent nutritional anemia in the pigs, each sow's udder was swabbed once daily with a saturated solution of ferrous sulphate.

In the supplemented groups in the first experiment, the basal ration was

altered to include either 6 or 12 percent of dried corn distillers' solubles or 12 percent alfalfa meal, largely at the expense of corn and soybean meal. The dried solubles was previously described (Fairbanks, Krider and Carroll, 1944). A fresh supply was obtained from the processor for each test. The alfalfa meal used in the first test was of average quality. In the second experiment a good quality dehydrated meal[5] containing 17 percent protein was fed. It was bright green in color and each pound, by assay, contained 41.3 mg. of carotene, 5.31 mg. of riboflavin and 18.3 mg. of niacin.

Basal Ration

Ingredients	*Pounds*	*Composition & Vitamin Content*	
Ground yellow corn	83.0	Crude protein	15.1 %
Expeller soybean meal	8.0	Calcium	0.77%
Menhaden fishmeal	2.0	Phosphorus	0.51%
Digester tankage	5.0	Manganese, p.p.m.	9.6(40)[3]
Ground limestone	0.5	Riboflavin, mg. per lb.	1.17[3]
Steamed bonemeal	0.5	Niacin, mg. per lb.	10.6[3]
Iodized salt	0.5	Pantothenic acid, mg. per lb.	2.28[4]
Fortified cod-liver oil	0.5		
	100.0		

Supplements to the basal diet in the second test were: either (a) crystalline vitamins (thiamin, riboflavin, niacin, pantothenic acid, pyridoxine and choline chloride); (b) a combination of six percent dried corn distillers' solubles and four percent of alfalfa meal; or (c) ten per cent of alfalfa meal. The crystalline vitamins were pre-mixed with soybeam meal to add the following amounts per 100 pounds of ration: 150 mg. thiamin, 150 mg. riboflavin, 500 mg. niacin, 600 mg. pantothenic acid, 250 mg. pyridoxine and 150 grams of choline chloride.

Results and Discussion

Gestation

The essential data are presented in table 1 (first test) and table 2 (second test).

The data of both tests indicate that breeding efficiency was increased by the addition of either dried corn distillers' solubles and alfalfa meal, alone or in combination, or crystalline B-vitamins to the basal ration as measured by services required per conception and by the average number of pigs farrowed per litter. Although the number of gilts used was not large, it appears that the water-soluble vitamins are essential for successful reproduction.

[3] Manganese sulphate added at the rate of ½ lb. per ton of feed in the second test.

[4] Assays through the courtesy of Hiram Walker & Sons, Inc. Peoria, Illinois, and Ralston Purina Company, St. Louis, Missouri.

[5] Kindly supplied through courtesy of Ralston Purina Company, St. Louis, Missouri.

The basal ration was inadequate for meeting the nutritive requirements of gestation although the gilts grew at a satisfactory rate.

An analysis of the data for both tests, using Students' "t" test for unpaired differences showed that the number of pigs farrowed by the sows which received alfalfa meal was significantly greater than the basal group

TABLE 1. RESULTS DURING GESTATION (1942–43 WINTER)

Items compared	Lot numbers and treatments			
	1 Basal	2 Basal +6% solubles[1]	3 Basal +12% solubles	4 Basal +12% alfalfa meal
Number of sows	5	10	10	4
Number of sows farrowed	5	8	8	4
Av. no. services per conception	2.0	1.4	1.3	1.0
Av. age at farrow, days	421	395	387	380
Av. daily gain from 225 lbs. to farrow, lbs.	1.44	1.26	1.35	1.61
Av. daily feed, lbs.	8.28	7.43	7.43	8.78
Av. no. pigs farrowed per litter	6.20	7.12	10.1	10.0
Av. birth weight of pigs, lbs.	2.39	2.42	2.24	2.29
Percentage of pigs farrowed:				
Strong	39	67	51	60
Medium	32	12	23	20
Weak	16	21	22	13
Dead	13	0	4	7
Immature	0	0	0	0

[1] Kindly supplied by Hiram Walker & Sons, Inc., Peoria, Illinois.

($t = 3.07$, odds $\leq 99:1$). The differences in birth weights were not significant in the first test, but in the second experiment the sows on the fortified diets produced pigs that were significantly heavier than the pigs from the basal group (odds $\leq 99:1$). Among the supplemented groups, the differences in birth weights and in number of pigs farrowed per litter were not significant statistically.

The pigs farrowed by the gilts fed the basal ration were not as strong and more were dead at birth than those farrowed by sows fed the fortified rations.

The value of the dried solubles and alfalfa meal, alone or in combination, as supplements to the basal ration is attributed to the water-soluble vitamins contained in these products. In addition to supplying the B-vitamins known to be required for growth, the alfalfa meal was probably supplying additional factors since the gilts fed ten or twelve percent alfalfa meal remained

relatively free from abnormalities in skin, hair, feet, legs and gaits while gilts in the other groups showed certain abnormalities.

Seven of the eight gilts on the basal ration conceived, but more services

TABLE 2. RESULTS DURING GESTATION (1943–44)

Items compared	Lot numbers and treatments			
	1 Basal	2 Basal +crystalline vitamins[1]	3 Basal +6% solubles[2] +4% alfalfa meal	4 Basal +10% alfalfa meal
Number of sows	3	3	3	3
Number of sows farrowed	2	3	3	3
Av. no. services per conception	2.0	1.0	1.3	1.0
Av. age at farrow, days	400	407	400	402
Av. daily gain, 225 lbs. to farrow, lbs.	1.34	1.47	1.52	1.36
Av. weight per sow before farrow, lbs.	405	491	426	421
Av. daily feed, lbs.	6.78	7.63	7.86	7.88
Av. no. pigs farrowed per litter	7.5	9.3	9.0	9.3
Av. birth weight of pigs, lbs.	1.95	2.63	2.84	2.73
Percentage of pigs farrowed:				
Strong	27	86	78	68
Medium	0	11	18	28
Weak	7	3	4	0
Dead	66	0	0	4
Immature	0	0	0	0

[1] Obtained through the courtesy of Lederle Laboratories, Inc., Pearl River, New York.
[2] Kindly supplied by Hiram Walker & Sons, Inc., Peoria, Illinois.

were required and fewer pigs, that were weaker, were farrowed. The gilt that would not conceive was mated several times and was marketed as a non-breeder.

Lactation

To test the true effect of a gestation ration the treatment of all lots should be standardized during the lactation period. This was done with most of the sows in the first experiment and all sows in the second test. The essential data are given in table 3 (first test) and table 4 (second test).

In both experiments the data indicate that the diet fed during gestation is an important factor in producing satisfactory results during lactation and must not be ignored when considering the question of high mortality among

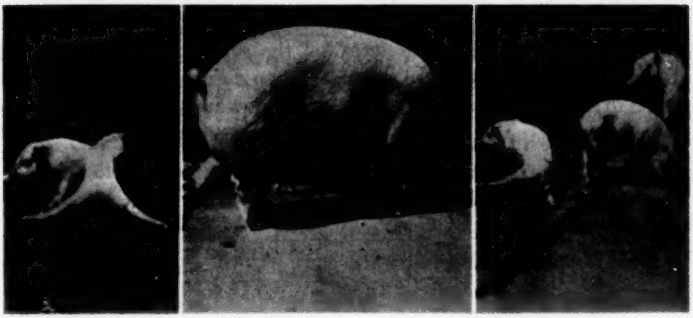

Figure 1. Deficiency symptoms produced by feeding the basal ration. These pigs were 43 days old when photo was taken. Only three pigs averaging ten pounds each were weaned at 56 days.

TABLE 3. RESULTS DURING LACTATION (1943 SPRING)

Items compared	Lot numbers and treatments					
	1	2		3		4
	Basal[1]	Basal +6% solubles	Basal +6% solubles	Basal +12% solubles	Basal +12% solubles	Basal +12% alfalfa meal
	Basal[2]	Basal	Basal +6% solubles	Basal	Basal +12% solubles	Basal
Number of sows farrowed	5	3	5	4	4	4
Av. no. of pigs farrowed per litter	6.2	6.3	8.6	9.8	10.5	10.0
Av. no. of pigs weaned per sow farrowed	0.8	3.0	3.6	4.0	5.0	8.25
Av. weaning weight per litter, lbs.	28	89	89	161	127	155
Av. weaning weight per pig, lbs.	14.0	20.0	19.8	20.2	19.1	18.8
Av. daily ration, sow and litter, lbs.	6.26	8.46	6.72	10.00	8.49	9.72
Percentage of pigs:						
Dead at birth	13	0	0	0	7	7
Died 1 to 3 days	58	26	18	38	28	8
Died 4 to 14 days	13	26	21	21	12	2
Died 15 to 56 days	3	0	13	0	5	0
Weaned	13	48	48	41	48	83

[1] Rations on this line are for gestation period.
[2] Rations on this line were given during lactation.

baby pigs. Nearly complete "lactation failure" resulted when the basal ration was fed during growth, gestation and lactation.

Even though the sows that were fed the supplemented diets during growth and gestation were fed the basal ration during lactation, they continued to raise a high percentage of their pigs to weaning age (56 days). This indicates that gestation rations are more important in promoting successful

TABLE 4. RESULTS DURING LACTATION (1944 SPRING)

Items compared	Lot numbers and treatments			
	1	2	3	4
	Basal[1]	Basal + crystalline vitamins	Basal+6% solubles +4% alfalfa meal	Basal+10% alfalfa meal
	Basal[2]	Basal	Basal	Basal
Av. no. pigs weaned per sow farrowed	0.5	4.6	7.7	7.7
Av. weaning weight per litter, lbs.	6.5	99.	194.	171.
Av. weaning weight per pig, lbs.	6.5	21.2	25.3	22.4
Av. daily ration, sow and litter, lbs.	—[3]	8.55	9.97	9.51
Percentage of pigs:				
Dead at birth	66	0	0	4
Died 1 to 3 days	7	18	11	7
Died 4 to 14 days	7	11	0	4
Died 15 to 56 days	13	21	4	3
Weaned	7	50	85	82

[1] Rations on this line are for gestation period.

[2] Rations on this line were given during lactation.

[3] One sow's pigs died soon after farrowing and the other sow had a very poor appetite, so daily feed is not reported.

lactation than commonly has been believed. The so-called residual effect is demonstrated again in these data and indicates that storage of known or unknown water-soluble factors in the sow's tissues is great enough to be manifested in very significant differences in the number of pigs that survive to weaning time. While only 13 percent and 7 percent of the basal pigs were weaned, 82 percent and 83 percent of the pigs from sows fed alfalfa meal survived although the latter sows and their litters received only the basal diet during the lactation period.

The results during lactation show that dried distillers' solubles, in the amounts fed, were not as effective as falfalfa meal or the combination of solubles and alfalfa meal in supplementing the basal ration. Apparently there is a supplementary or complimentary effect of alfalfa meal and solubles.

Their supplementary effect, singly or combination, is attributed to their content of water-soluble vitamins.

Although the results were obtained on 36 sows and their progeny, the differences are so large that we consider the gestation-lactation phase of swine production as a critical period, nutritionally. More data are needed and research on the nutritive requirements of gestation and lactation will be necessary before we can predict with certainty the adequacy or the inadequacy of diets. This is substantiated by the reports of other workers as well as this study. Many rations composed of commonly used ingredients have proved to be inadequate for successful gestation and lactation performance under continuous drylot feeding.

The data from lot 2 in the second test show that the crystalline vitamins are as effective as natural carriers in meeting the nutritive requirements of gestation in regard to number of pigs farrowed. This group farrowed a higher percentage of strong pigs than any other group. This does not substantiate the Wisconsin report (Cunha *et al.*, 1944) which indicated that certain crystalline B-vitamins are detrimental. Although certain of the B_2-factors are known to be stored in the tissues, the data indicate that sows fed either alfalfa meal or the combination of solubles and alfalfa meal either stored more of the known factors than the sows fed the crystalline vitamins or stored additional required factors which were necessary for survival of the pigs during lactation during which all the sows were fed the inadequate basal ration.

During the second experiment, all pigs were bled twice weekly to study the effect of the diets upon certain blood components. Some pigs were posted before death and tissue samples were obtained for histological studies. These data and post mortem findings will be reported in a later paper.

Conclusions

1. A basal ration composed of yellow corn, soybean meal, tankage, fish meal, fortified cod-liver oil and minerals was nutritionally inadequate for gestation and lactation under drylot conditions.

2. The addition of either six or twelve percent of dried corn distillers' solubles, a combination of alfalfa meal and dried solubles, alfalfa meal, or six crystalline B-vitamins improved breeding efficiency, fertility and the strength of the pigs farrowed. The value of the alfalfa meal and the solubles is attributed to the water-soluble vitamins, known or unknown, contained in these products.

3. Feeding during gestation is an important factor for satisfactory results during lactation and must not be ignored when considering the question of high mortality among baby pigs.

4. The residual effect of feeding rations fortified with B_2-complex supplements during gestation was manifested during the lactation period when all groups received the basal ration. Only 13 percent and 7 percent of the pigs were weaned by the basal sows, while 83 percent and 82 percent of the pigs were weaned by the sows fed alfalfa meal during gestation, and the basal ration during lactation. The importance of adequate nutrition during gestation and the value of alfalfa meal as a vitamin B_2-complex supplement is clearly demonstrated. Sows fed the combination of 6 percent solubles and 4 percent alfalfa meal during gestation weaned 85 percent of their pigs although they were fed the basal ration during lactation. The six crystalline vitamins were effective in supplementing the basal ration, but the residual effect was not manifested to the same degree as in the groups fed natural vitamin carriers. This indicates either a greater tissue storage of the known factors or a storage of unknown factors by the groups fed alfalfa meal or the solubles-alfalfa meal combination.

5. In the interpretation of the differences in the lactation performance of sows due to ration differences, consideration of the adequacy of the rations fed during the gestation and even the growing periods should be considered.

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DISTILLERS' BY-PRODUCTS IN SWINE RATIONS

III. DRIED CORN DISTILLERS' SOLUBLES, ALFALFA MEAL, AND CRYSTALLINE B-VITAMINS COMPARED FOR GROWING-FATTENING PIGS IN DRYLOT[1]

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Introduction

IN PREVIOUS studies at the Illinois Station, it was shown with growing-fattening pigs in drylot that the supplementation of a basal ration composed of commonly used ingredients with either dried corn distillers' solubles, corn distillers' dried grains with solubles, or alfalfa meal was effective (Fairbanks, Krider, and Carroll, 1944; Krider, Fairbanks and Carroll, 1944). Furthermore, the pigs fed fortified rations in a creep to weaning and then changed to the basal growing-fattening ration manifested a residual effect. When young pigs received only their dam's milk during the lactation phase, the pigs from the sows fed the fortified rations manifested a residual effect of the higher nutritional regime in the weaning to market period. It appeared that growth-factors in the dried corn distillers' solubles were transferred through the milk to the young pigs, thus enabling them to be more viable than the control pigs during the post-weaning period.

The nutritional inadequacy of a basal ration composed of yellow corn, wheat flour middlings, soybean meal, tankage, fish meal, fortified cod-liver oil and minerals for growing-fattening pigs in drylot was demonstrated. Moreover, this ration was improved by supplementing it with distillers' by-products or alfalfa meal. The improvement was attributed to water-soluble vitamins, known and/or unknown, contained in these products. Corn distillers' solubles produced as rapid growth as alfalfa meal in these growing-fattening rations. Alfalfa meal was a more adequate supplement in promoting normal development of feet and legs than the dried solubles, but in the appearance of skin and hair coat the two products were more comparable, especially during the last eight weeks of the test (Krider, Fairbanks and Carroll, 1944). Bohstedt, Grummer and Ross (1943) have also reported that dried distillers' solubles has a "favorable supplementary effect" when fed to growing-fattening swine in drylot. Synold (1944) reported that distillers' dried solubles used as a vitamin source effectively supplemented drylot

[1] This investigation was made possible by the donation of funds and products to the University of Illinois by Hiram Walker & Sons, Inc., Peoria, Illinois. The crystalline vitamins were supplied by Lederle Laboratories, Inc., Pearl River, New York.

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rations containing either a small quantity of animal protein or all-vegetable protein.

The experiment reported herein was designed to supplement and confirm previous work. The addition to the basal ration of crystalline thiamin, riboflavin, niacin, pantothenic acid, pyridoxine and choline was made to determine whether these vitamins would correct, partly or completely, the inadequacies of the basal ration that has consistently given poor growth and high death losses in drylot feeding. The objects were: 1. To determine the value of fortifying an inadequate basal ration of ground yellow corn, wheat flour middlings, soybean meal, tankage, fish meal, minerals and fortified cod-liver oil with either six percent dried corn distillers' solubles or ten percent alfalfa meal for growing-fattening pigs in drylot. 2. To determine whether the six synthetic B-vitamins would correct, partly or completely, the deficiencies of the inadequate basal ration that has consistently given poor growth and high death losses in drylot. 3. To observe the residual effect, if any, of fortifying the lactation ration with dried corn distillers' solubles upon the livability of the pigs during the growing-fattening period.

Experimental Procedure

The pigs used were produced by gilts that had been in drylot continuously from birth, and their nutritional history was known. During lactation, two treatments were studied with the sows and litters. Some received a basal ration of ground yellow corn, soybean meal, tankage, fish meal, minerals and fortified cod-liver oil while the others received the basal ration supplemented with dried corn distillers' solubles. This phase of the experiment is not reported.

At weaning (56 days), each litter of pigs was allotted to the four lots and each lot was equalized according to weight, litter, type, condition, sex and previous treatment.

The twenty-percent-total-protein-rations fed to the pigs from weaning to 100 pounds live weight with compositions are given in table 1. From 100 pounds to market weight (225 pounds), mixtures containing 15 percent total protein were fed. The rations were approximately equalized for total protein, calcium, phosphorus and manganese.

The pigs were weighed individually every two weeks, and near the end of the experiment individual weekly weights were taken. Each pig was weighed off the test on the weigh day at which its live weight approximated 225 pounds.

For lot 2 the crystalline vitamins were added to the basal ration. A small quantity of corn starch was used as a carrier for thiamin hydrochloride, riboflavin, nicotinic acid, calcium pantothenate and pyridoxine, giving a

premix, which was then added to five pounds of the basal ration to give a second premix. The choline chloride was added to the latter premix and

TABLE 1. RATIONS (20% PROTEIN) FED FROM WEANING TO 100 POUNDS

Ingredients and components of rations	Lot numbers and treatments			
	1 Basal	2 Basal+6 crystalline B-vitamins[1]	3 Basal+6% dried corn distillers' solubles	4 Basal+10% alfalfa meal
Ingredients (in pounds):				
Ground yellow corn	590	590	568	510
Wheat flour middlings	150	150	150	150
Soybean meal (expeller)	125	125	90	110
Tankage (60% protein)	80	80	80	80
Fish meal (Menhaden, 60% protein)	35	35	35	35
Dried corn distillers' solubles	—	—	60	—
Alfalfa meal, dehydrated	—	—	—	100
Fortified cod-liver oil	5	5	5	5
Limestone	5	5	7	—
Steamed bonemeal	5	5	—	5
Iodized salt	5	5	5	5
Total	1000	1000	1000	1000
Manganous sulphate per 1000 lbs.	2 oz.	2 oz.	2 oz.	2 oz.
Composition, by analyses:				
Fiber, percent	2.96	3.36	2.98	5.90
Manganese, p.p.m.	52	47	66	59
Riboflavin, mg. per lb.[2]	1.27	2.27	1.36	1.41
Niacin, mg. per lb.[2]	15.39	19.70	16.43	17.39
Pantothenic acid, mg. per lb.[2]	5.86	10.08	5.68	5.95
Folic acid (L. casei factor),[3] p.p.m.	0.58	—	—	—
Choline chloride, mg. per lb.[4]	479	1979	606	489

[1] The following amounts of crystalline B-vitamins were added per 100 pounds of feed: thiamin hydrochloride, 150 mg; riboflavin, 150 mg.; nicotinic acid, 500 mg.; calcium pantothenate, 600 mg.; pyridoxine, 250 mg.; and choline chloride, 150 gm.

[2] Riboflavin and pantothenic acid determined by microbiological method, nicotinic acid determined by microbiological and chemical methods. Courtesy Hiram Walker & Sons, Inc., Peoria, Illinois, and Ralston Purina Company, St. Louis, Missouri.

[3] Courtesy Dr. T. H. Jukes, Lederle Laboratories, Inc., Pearl River, New York. The assay was made by the method of Snell and Peterson (J. Bact. 39: 273–285, 1940), following a taka-diastase and papain digestion of the sample.

[4] Estimated from values obtained in literature (Engel, R. W., Jour. Nutrition 25: 441–446, 1943; Rhian, M., R. J. Evans and J. L. St. John, Jour. Nutrition 25: 1–5, 1943).

small amounts of the basal diet were added until the complete mixture was made ready for self-feeding.

In an earlier report (Fairbanks, Krider and Carroll, 1944) the description and composition of the dried corn distillers' solubles was given. The fresh product used in this study was processed in the same way as the product used in previous studies.

The dehydrated alfalfa meal used was made from whole hay and contained 14.6 percent crude protein. This is about the same protein content as the average analyses of 14.7 percent reported by Morrison (1937) for alfalfa hay.

Results and Discussion

The essential data for the four lots of pigs from weaning to market are presented in table 2. The relative growth curves of the survivors in the lots during the first 21 weeks of the post-weaning period are shown in figure 1. The average daily gains were studied statistically by analysis of variance as described by Snedecor (1940) for groups with unequal numbers.

TABLE 2. THE RESULTS OF ADDING (1) CRYSTALLINE B-VITAMINS,* OR (2) SIX PERCENT DRIED CORN DISTILLERS' SOLUBLES OR (3) TEN PERCENT ALFALFA MEAL, TO THE BASAL RATION FOR GROWING-FATTENING PIGS IN DRYLOT FROM WEANING TO MARKET, SPRING 1943. (ALL PIGS SELF-FED)

Items compared	Lot numbers and treatments			
	1 Basal	2 Basal+ crystalline B-vitamins*	3 Basal+6% dried corn distillers' solubles	4 Basal+10% alfalfa meal
No. of pigs started	13	11	11	11
No. of pigs died during test	4	1	2	2
Av. initial weight, lbs.	21.3	20.4	21.8	21.4
Av. final weight, lbs.	185.7	217.9	215.0	214.9
Av. daily gain, lbs.**	0.79	1.17	0.93	1.12
Av. daily feed, lbs.**	3.24	4.03	3.64	4.14
Feed eaten for 100 lbs. gain, lbs.**	419	377	397	405

* Thiamin hydrochloride, riboflavin, nicotinic acid, calcium pantothenate, pyridoxine and choline chloride.
** For the pigs that finished.

Basal Ration Inadequate

The slow growth rate, 31 percent death loss, and the symptoms of the pigs clearly demonstrated the inadequacy of the basal ration. The performance of the basal group was about the same as previously reported in other experiments (Fairbanks, Krider and Carroll, 1944; Krider, Fairbanks and Car-

roll, 1944), although manganous sulphate was added to the basal mixture to provide about 50 p.p.m. of manganese in the ration. This confirmed the belief of the authors that even though the basal ration unsupplemented with manganous sulphate contained only 10–20 p.p.m. of manganese, this element was not the first limiting factor in the ration for growing-fattening pigs. The

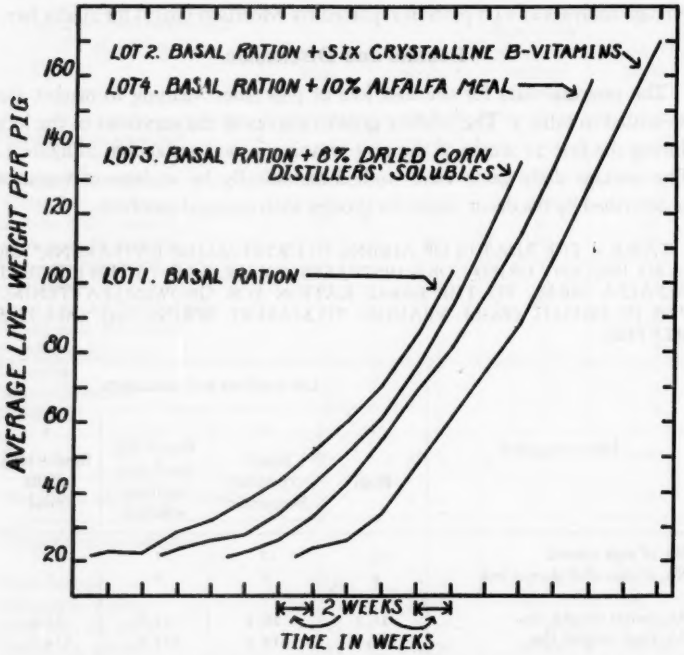

Figure 1. Growth curves of the groups of pigs used in the experiments reported.

recent report of Johnson (1944) indicates that 7 to 10 p.p.m. of manganese in the diet will induce satisfactory growth rates from weaning to market weights.

The surviving pigs in the basal lot gained significantly ($P < .05$) slower than those in lot 2 and lot 4. While lot 3 gained 16 percent more rapidly than the basal group, this was not statistically significant. However, the practical significance of supplementing the basal ration with dried corn distillers' solubles should not be overlooked.

Gross symptoms noted in the basal lot were: slow growth, looseness of feces and scouring, emaciation, rough hair coats, listlessness, dermatitis,

fence chewing, coprophagia, wabbly gaits with some incoordination and occasional "goose stepping." Although the average daily feed consumption was lowest in this lot, anorexia was not evident because the pigs worked the feeders much of the time and consumed over four percent of their body weight as feed daily. They seemed to crave something that was lacking in the basal ration. If the assays in table 1 are correct, the basal diet was supplying more than the published requirements for riboflavin, niacin and pantothenic acid. The basal ration was assayed for the L. casei factor (folic acid),[4] and contained 0.58 micrograms per gram. The minimum requirement of the chick is about 0.4 micrograms of L. casei factor per gram of diet. Although it is not known whether the pig requires the L. casei factor, unpublished work at the Illinois Station shows that the addition of a concentrate which contains folic acid gives a growth response in pigs fed certain diets.

As previously reported by Krider, Fairbanks and Carroll (1944), a deficiency of either thiamin or pyridoxine in the basal diet was not suspected. According to the best available estimates of the choline composition of the feeds used, one pound of the basal ration supplied 479 milligrams of choline. Wintrobe *et al.* (1942) fed 474 milligrams of choline per 100 pounds of pig daily. This level gave complete protection and was considered adequate. Therefore it appears that the rations fed in this test were not deficient in choline.

Even though the basal ration appears to be adequate in the vitamins known to be required by the pig, if published requirements are accepted and the assays are reasonably correct, the supplementation of this ration with the six crystalline vitamins gave a marked growth response. This would indicate that: either (1) the assay values are too high; (2) the published requirements are too low; or (3) the limiting vitamin or vitamins supplied in the basal diet are not as available to the pig as the crystalline vitamins added to the same ration.

Addition of the Six Crystalline B-Vitamins to Basal Ration Significantly Increased Growth Rates

Most rapid growth was obtained in lot 2, indicating that the six crystalline B-vitamins effectively supplemented the deficient basal diet ($P < .05$). In comparing the average daily gains of lots 1 and 2, the odds were 45:1 that the difference was not due to chance. Lot 2 also gained significantly more rapidly than lot 3 ($P < .05$), but the difference between the gains of lot 2 and lot 4 was not statistically significant. Only 377 pounds of feed were required to produce 100 pounds of gain in lot 2, which was 10 percent less feed than was required in the basal group (lot 1).

[4] Courtesy Dr. T. H. Jukes, Lederle Laboratories, Inc., Pearl River, New York.

A comparison of the assay values of the rations fed to lots 1 and 2 (see table 1) shows that approximately 67 percent of the riboflavin, 86 percent of the nicotinic acid and 70 percent of the pantothenic acid added to the basal ration for lot 2 was actually recovered in the assays. It was assumed that the pigs received the quantity of vitamins added to the basal ration. If we assume that the pigs consumed feed equivalent to four percent of their body weight daily, the following amounts of the crystalline vitamins were consumed per 100 pounds of body weight daily in addition to the amounts contained in the basal ration: thiamin hydrochloride, 3 milligrams; riboflavin, 6 milligrams; nicotinic acid, 20 milligrams; calcium pantothenate (dextrorotory), 24 milligrams; pyridoxine, 10 milligrams; and choline chloride, 6 grams. Actually the pigs in lot 2 consumed feed equivalent to 4.9 percent of their live weight daily during the first eleven weeks of the test.

Even though the average growth rate in lot 2 was approximately "normal," the gross symptoms indicated that this ration was not nutritionally complete. A mild dermatitis was observed which was most noticeable during the eighth and ninth weeks of the test. There were some instances of very slight "goose stepping." These abnormalities became less evident after the pigs reached 75 to 100 pounds live weight. During the remainder of the test these pigs appeared to be almost normal although they were not as sound in feet and legs as the pigs that received alfalfa meal.

The pig that died in lot 2 was very thrifty and was in excellent condition the day before death. A post-mortem examination was made. The cause of death was undetermined but evidence indicated that it was not nutritional.

Supplementary Value of Dried Corn Distillers' Solubles

Although the lot of pigs fed six percent of dried corn distillers' solubles did not gain as rapidly as lot 2 (crystalline vitamins) or lot 4 (alfalfa meal), they gained 16 percent more rapidly than lot 1 (basal) and required 5.2 percent less feed. The average daily gains in lot 3 were more uniform than in any other lot with a coefficient of variability of 14 percent. Death losses were fewer than in the basal lot which confirms previous observations.

There were two very severe incidences of "goose stepping" in the lot fed dried corn distillers' solubles. In the lot fed the crystalline vitamins, "goose stepping" and other abnormal gaits were present but not so severe as the two cases in lot 3. The pigs in lot 4 were apparently normal. Since lot 3 occupied a pen between lot 2 and lot 4 in the same barn, it is difficult to assign any cause other than borderline nutrition. One of these "goose stepping" pigs was fed the basal diet during the lactation period. Considerable softness of feces, and scouring, were noted much of the time in lot 3. During the eighth and ninth weeks on test the incidences of dermatitis were high in

this lot and similar to lots 1 and 2, but after about 14 weeks on test the skins "cleared up" and the hair coats became sleek. The abnormal gaits, including crossing-over, some incoordination and "goose stepping," were observed before the pigs reached 75 pounds in weight.

In past experiments the daily gains of pigs fed the solubles have been more rapid than the gains made in this test.

Alfalfa Meal Effectively Supplemented the Basal Ration

The feet, legs, gaits, hair coats, and skins of the pigs fed alfalfa meal were more nearly normal than those of any other lot. Their average daily gains were not significantly slower than the gains in lot 2 (crystalline vitamins). Although the feed required to produce 100 pounds of gain was almost seven percent higher in lot 4 than in lot 2, little significance is assigned to these values.

These results demonstrate the value of alfalfa meal as a source of the water-soluble factors needed to supplement the basal ration for growing-fattening pigs that have been continuously in drylot from birth. Observations and symptoms indicated that the alfalfa meal was the most effective and economical supplement used in the test. The ration containing alfalfa meal was also the most complete nutritionally.

A Note on Residual Effects

This experiment was not designed primarily to study in detail the residual effect noted in earlier experiments at the Illinois Station. During the suckling period the dams of the pigs used in this test received two treatments; that is, some sows received a basal ration of corn, soybean meal, tankage, fish meal, minerals and fortified cod-liver oil while other sows received the basal ration supplemented with dried corn distillers' solubles. The pigs at weaning were distributed equally to the four lots. Eighteen of the 46 pigs came from dams fed the basal ration fortified with dried corn distillers' solubles. Only one of these pigs representing 5.6 percent died while six out of 28 pigs from sows fed the basal ration died. The latter represented a 21.4 percent death loss. Although definite conclusions may not be justified, the evidence clearly substantiates the findings of earlier experiments that after weaning the pigs from sows fed more nearly adequate rations during lactation manifested a residual effect of the higher nutritional regime.

Nerve Studies

Three pigs were autopsied at the close of the test by the Department of Animal Pathology and Hygiene.[5] A severe "goose stepper" (see figure 2), a

[5] Courtesy of Dr. C. C. Morrill, Department of Animal Pathology and Hygiene, University of Illinois, Urbana, Illinois.

mild "goose stepper," and a pig that appeared normal were used. Histopathological examination was made on sections from the lumbar spinal cord and the sciatic nerve.

The nerve sections were stained with the hematoxylin-eosin technique and with Mahon's procedure and showed the following changes:

In the severe "goose stepper" a rather marked demyelination of the fibers of the sciatic nerve was present accompanied by moderate proliferation of the Schwann cells. There was also evidence of considerable edema surrounding some of the nerve bundles. In the pig that "goose stepped" slightly there was evidence of mild demyelination of the sciatic nerve, but this was not

Figure 2. The most extreme case of sickled hocks, weak rear legs, incoordination and "goose stepping" encountered in the test. This pig remained thrifty and gained 0.97 pounds daily from an initial weight of 18 pounds to a final weight of 225 pounds. Nerve studies were made on the lumbar spinal cord and the sciatic nerve.

accompanied by any appreciable proliferation of the Schwann cells. No significant changes were noted in the pig that appeared normal which was a pig from the lot receiving alfalfa meal in the ration. The external symptoms observed were correlated with the nerve changes noted.

Summary and Conclusions

Weanling pigs that had been confined in drylot from birth were fed a basal ration of ground yellow corn, wheat flour middlings, soybean meal, fish meal, tankage, minerals and fortified cod-liver oil or the basal ration supplemented with either (1) crystalline B-vitamins (2) six percent dried corn distillers' solubles, or (3) ten percent of alfalfa meal. The basal ration was very inadequate even though chemical analyses and vitamin assays indicated that it was adequate in the nutrients known to be required by the pig.

Supplementing the basal ration with six percent of dried corn distillers' solubles increased the gains 16 percent and death losses were decreased.

When the basal ration was supplemented with thiamin hydrochloride,

riboflavin, nicotinic acid, calcium pantothenate, pyridoxine and choline chloride, growth response was increased and death losses were reduced from 31 to 9 percent. This supplementation was not as complete nutritionally as the addition of ten percent of alfalfa meal, but was more effective than dried corn distillers' solubles. The additional response of the pigs to feeding the crystaline B-vitamins would lead one to suspect that: either (1) the vitamin assay values may be too high; (2) the published vitamin requirements for the pig may be too low; (3) the vitamins in natural ingredients may not be as available to the pig as to the microorganisms used in microbiological assays; or (4) to a combination of two or more of these factors.

Alfalfa meal was a more adequate supplement in promoting normal development of feet, legs, gaits and thrift than the other supplements. It may have been supplying factors in addition to the B-vitamins known to be required by the pig.

Pigs that had nursed sows fed a fortified ration during lactation manifested a residual effect of the higher nutritional regime during the post-weaning tests. Death losses during the growing-fattening period were reduced fourfold by fortification of the lactation ration.

Moderate proliferation of the Schwann cells and marked demyelination of the fibers of the sciatic nerve was present in a pig that "goose stepped" severely. The changes in the nerves of a mildly affected pig were similar, but less marked while nerves from a normal pig showed no significant changes.

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DIGESTIBILITY OF GREEN MUNGBEAN SEED BY LAMBS

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Introduction

GREEN mungbeans (*Phaseolus aureus*) are a crop that has been increasing rapidly in acreage in Oklahoma and some surrounding states the past few years. The crop is used as a late catch-crop or a crop to follow oats or other small grain. The green seed is sprouted for human consumption and has had a very ready market the past few years. Commercial sprouters can not make use of cracked beans, and feed mixers have asked about using them as a source of protein in the preparation of mixed feeds. Farmers often take the cracked beans back home as livestock feed and include them in livestock rations.

Ground green mungbeans were fed to fattening pigs at the Oklahoma Station (Blizzard, 1942) and satisfactorily replaced cottonseed meal in a protein mix of 2 parts meat scraps, 1 part cottonseed meal, and 1 part dehydrated alfalfa leaf meal. They were an unsatisfactory substitute for the protein of cottonseed meal and meat scraps when the mungbeans and dehydrated alfalfa were fed as the sole supplements to corn.

Cracked mungbeans were used as a protein supplement in two fattening trials with feeder lambs at the Oklahoma Station (Blizzard, 1944). The beans were used to supply from one-half to two-thirds of the protein required to balance a ration of corn and prairie hay; cottonseed meal supplied the remainder of the protein required. It was necessary to feed cottonseed meal as a supplement to meet the protein requirements of the lambs because the beans were not palatable when fed in excess of .35 lbs. daily. In one trial with dairy cows at the Oklahoma Station (Blizzard *et al.*, 1945) 300 pounds of ground mungbeans replaced 150 pounds of ground corn and 150 pounds of cottonseed meal. The mungbeans replaced 43 percent of the corn and 60 percent of the cottonseed meal of the control ration.

Procedure

Two digestion trials were conducted to determine the digestibility of the green mungbeans. Eight fine-wool wethers were started on a digestion experiment during the summer of 1943, but only four of the lambs completed the trial; one of the lambs failed to consume the basal ration of prairie hay, and the other three would not consume the basal ration of 454 gms. of prairie

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hay and the 136 gms. of green mungbeans that were added as a supplement. The four wethers that completed the study averaged 90 lbs. at the start of the experiment. Eight fine-wool feeder lambs were used in the second trial conducted during the winter of 1943–44. These lambs averaged 70 lbs. at the start of the experiment. They were fed 600 gms. of prairie hay daily for the basal ration, and the mungbeans were added to the basal ration at the rate of 136 gms. daily.

The wethers and lambs were fed each test ration for a 10-day preliminary period in a 3′×5′ pen and then placed in false bottom cages similar to those described by Forbes (1915). The feeds for each feeding were weighed and stored in paper bags prior to the experiment. Each lamb was fed from an open

TABLE 1. PERCENTAGE COMPOSITION OF THE FEEDS USED IN DIGESTION TRIALS

Trial 1.—July 20, 1943, to September 3, 1943

Feed	H_2O	Protein	Fat	Crude fiber	Ash	Nitrogen-free extract
Prairie hay	6.65	3.88	2.17	31.98	6.41	48.91
Green mungbeans	8.81	22.31	1.18	3.98	3.94	59.78
Trial 2.—January 2, 1944, to March 1, 1944						
Prairie hay	9.48	4.03	2.39	23.49	4.70	46.91
Green mungbeans	11.35	24.34	.86	2.99	4.71	55.75

bucket while in the preliminary pen but in a specially constructed feeder while in the cage. Fresh, clean water was placed before the lambs at each morning and evening feeding and allowed to remain until the next feeding. Approximately 8 grams of salt were added to the feed each morning and evening.

Daily fecal collections were made at the same time each morning. Each collection was dried separately for 24 hours in an electric heater and was then weighed and sealed. At the close of the 10-day collection period, the feces were thoroughly mixed and sampled for chemical analysis. Urine collections were not made on the first trial. In the second trial they were made in glass jars, acidified with sulphuric acid, and stored for the duration of the collection period. The volume was then measured and an aliquot secured for chemical analysis.

Results and Discussion

The apparent digestion coefficients of the rations as secured from feeding

the four wethers in the first trial and the eight lambs in the second trial are given in table 2. The apparent digestion coefficient of the protein in the mungbeans, as determined by difference, for each of the four wethers used in the first trial was 82.0, 72.4, 79.7, and 74.2 percent respectively and averaged 77.1 percent. The coefficients, as found by difference, for the nitrogen-free extract and small amounts of fat and fiber were nearly always in excess of 100 percent.

TABLE 2. THE APPARENT DIGESTIBILITY OF PRAIRIE HAY AND OF PRAIRIE HAY AND GREEN MUNGBEANS

Subject number	Protein digestion coef. for ration		Fat digestion coef. for ration		Crude fiber digestion coef. for ration		Nitrogen-free extract digest-coef. for ration	
	Hay	Hay and beans	Hay	Hay and beans	Hay	Hay and beans	Hay	Hay and beans
Trial 1.—4 yearling wethers								
308	−4.9	48.9	11.4	35.4	50.0	51.5	32.5	53.0
345	−6.0	45.4	9.0	36.3	41.5	51.7	25.9	51.6
374	000	44.2	15.7	32.8	47.5	44.9	31.7	48.3
393	−5.5	50.3	4.2	34.8	48.8	45.0	32.5	49.4
Average	−4.3	47.2	10.1	34.8	46.9	48.3	30.6	50.6
Trial 2.—8 wether lambs								
59	17.5	56.6	25.0	40.8	56.5	55.8	48.0	57.6
91	22.2	51.0	42.4	36.0	60.1	52.6	51.1	59.9
110	15.0	51.3	36.8	33.3	48.4	50.1	44.1	54.6
118	8.4	58.8	25.5	43.3	49.1	52.1	47.0	56.6
139	19.2	56.8	40.0	33.5	55.4	54.3	48.3	62.0
156	17.9	55.7	34.8	41.0	51.1		46.7	
157	16.0	56.5	26.5	41.0	54.5	64.2	49.7	55.3
172	14.1	57.0	28.3	44.2	58.5	65.3	50.2	54.7
Average	16.3	55.5	32.4	38.2	54.2	55.9	48.2	57.1

In the second trial a better quality of prairie hay was fed the lambs than had been fed the wethers in the first trial; consequently, they would consume larger amounts. The digestibility of the fat and fiber again were usually in excess of 100 percent, but the beans contained only .86 percent fat and 2.99 percent fiber. The apparent digestion coefficients of the protein and nitrogen-free extract of the beans, as determined by difference, in the second trial are given in table 3.

In this trial the mungbeans furnished 63.3 percent of the protein intake

Apparently the mungbeans decidedly stimulated the appetite of the lambs for the low-grade prairie hay because they ate readily during the trial but would barely clean up their allowance of unsupplemented hay during the preliminary period. Their ability to digest the fat, fiber, and nitrogen-free-extract in the prairie hay must have been enhanced because average digestion coefficients of the mungbeans, as determined by difference, were in excess of 100 percent.

In the second trial, the digestion coefficient of the nitrogen-free-extract in the beans was 90.0 percent digestible, by difference, while the coefficients for fat and fiber were in excess of 100 percent as in the previous trial. There

TABLE 3. THE APPARENT DIGESTIBILITY OF THE PROTFIN AND NITROGEN-FREE-EXTRACT OF GREEN MUNGBEAN SEED AS DETERMINED BY DIFFERENCE WITH WETHER LAMBS

Lamb No.	Protein digestion coefficients	Nitrogen-free-extract digestion coefficients
59	86.1	92.7
91	76.3	103.5
110	76.0	78.8
118	89.8	88.0
139	86.3	113.4
156	84.4	85.5
157	85.8	81.7
172	86.8	76.5
Average	84.0	90.0

are so little fat and fiber in mungbeans that their apparent digestion coefficients would be difficult to determine accurately using a basal ration such as was used in this study.

The protein in green mungbeans was found by Briggs (1945) to compare favorably in apparent digestibility to the protein found in cottonseed meal, peanut meal and soybean meal. Those meals were fed in the above order to the wether lambs used in the second experiment following the feeding of the mungbeans. The meals were fed at a level of 73.4 gm. per day and hence supplied approximately the same protein content as the addition of 136 gm. of mungbeans to the basal ration of prairie hay. The apparent digestion coefficient of the protein in the ration supplemented by cottonseed meal was 52.0 percent and the digestibility as determined by difference of the cottonseed meal was 80.3 percent. The ration supplemented with peanut meal was 58.2 percent digestible and the meal 90.7 percent digestible. The corresponding values for the ration supplemented with soybean meal and for the soy-

beans were 59.5 and 92.1 percent, respectively. The mungbeans improved the digestibility of the prairie hay basal ration in the same manner as did the meals.

The values of Miller and Morrison (1944) for the metabolic and endogenous nitrogen of lambs were used in calculating the biological value of the protein in the hay-mungbean ration. The value was 73. The corresponding values found by Blizzard, *et al.* (1945) in a succeeding study were 79 for cottonseed meal, 69 for peanut meal, and 76 for soybean meal.

It appears from these data that mungbeans may be used as a satisfactory source of protein in the ration, providing they are not added in quantities large enough to lower the palatability of the ration. They can be used satisfactorily to supply at least a portion of the protein required.

Summary

The protein of green mungbeans was found to be quite digestible. In digestion experiments with four yearling fine-wool wethers the apparent digestion coefficient of protein, determined by difference, averaged 77.1 percent when the beans were added to very low grade prairie hay. General improvement that resulted in the ration led to apparent digestion coefficients of over 100 for the fat, fiber, and nitrogen-free-extract in the beans.

In a second trial, conducted with eight fine-wool wether lambs, the beans were added to a better grade of hay than used in the first trial. In this trial the apparent average digestion coefficient of the protein in the beans was 84.0 percent; the nitrogen-free-extract had an apparent digestion coefficient of 90.0 percent; and the coefficients for fat and fiber were again in excess of 100 percent. Studies with the wether lambs showed the biological value of the protein in rations of prairie hay and mungbeans to be similar to those found when the same hay was supplemented with more commonly used sources of vegetable protein.

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METHIONINE INCREASES THE VALUE OF UREA FOR LAMBS

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IT HAS been demonstrated that lambs are able to utilize urea nitrogen for maintenance and growth (Harris and Mitchell, 1941). Feed lot trials by Willman, Morrison and Klosterman (1944), however, show that urea has little or no value as a protein supplement when fed to fattening lambs with a ration of natural feeds. In four successive years the addition of linseed meal to a ration of yellow corn, corn silage and limited hay resulted in an improvement in the rate of gain, whereas, the addition of urea caused no improvement. These results suggested that the utilization of urea for protein synthesis in the rumen may have been very inefficient or that the protein formed by the microorganisms was of low quality, and, therefore, it could not be efficiently converted into body tissue by the lambs. It appeared of interest, therefore, to test the value of methionine as a supplement to a ration containing urea.

A basal diet was made to contain alfalfa meal 5.0 parts, ground timothy hay 29.0, cane molasses 5.0, yellow corn 12.0, ground oats 8.0, brewer's yeast 0.9, irradiated yeast 0.1, corn oil 1.3, and minerals[3] 0.88 parts. To make the different experimental rations the following amounts of nitrogen supplements to be tested were added to the basal diet: linseed meal, 9.54 parts; urea 1.25; urea 1.25 plus sodium sulfate 1.06; urea 1.02 plus methionine[4] 1.11 parts. Limestone and dicalcium phosphate were added to equalize the calcium and phosphorus contents of the diets, water to equalize the moisture, and corn starch to make each ration contain 100 parts. In the urea-sulfate-ration sodium sulfate was used to supply the same amount of sulfur as did the methionine.

The chemical composition of the rations is shown in table 1.

The rations were fed to five lambs in a balance study of change-over design, each lamb receiving each ration in the course of the test. After the intake of the lambs was established they were maintained at a constant feed intake for a 7-day preliminary period and a 10-day collection period. At the end of the collection the rations were changed suddenly and after levels of intakes were again established the process was repeated. A composite sam-

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[3] Composed of sodium chloride 72.65, magnesium carbonate 19.1, ferric citrate 7.47, copper sulfate 0.08, manganese sulfate 0.58, potassium aluminum sulfate 0.04, potassium iodide 0.02, cobalt chloride 0.04, and zinc carbonate 0.02 parts.

[4] The methionine used in this study was kindly furnished by E. I. du Pont de Nemours and Co., Wilmington, Del.

ple of urine and feces was preserved for analyses. Body weights were taken on two days at the start and at the end of the collection period as a measure of the change in weight.

The results of the growth and balance data are summarized in table 2. The values represent averages for five lambs on each treatment.

From these data it becomes evident that the addition of urea to the basal ration increased the rate of gain and the amount of nitrogen stored. Extra inorganic sulfur as sodium sulfate had no apparent effect. The addition of

TABLE 1. COMPOSITION OF THE RATIONS IN PERCENT

Ration	Dry matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash
Basal	91.70	6.55	2.59	13.13	65.35	3.88
Urea	92.64	10.28	2.39	12.70	63.31	3.96
Urea+SO_4	92.89	9.97	2.40	13.12	62.37	5.03
Urea+methionine	92.32	10.08	2.41	13.31	62.54	3.98
Linseed meal	92.02	10.58	2.35	13.67	61.21	4.21

TABLE 2. EFFECT OF NITROGEN SUPPLEMENTS ON THE RATE OF GAIN AND NITROGEN BALANCE OF LAMBS

Ration	Daily gain in weight	Nitrogen balance	True digestibility of nitrogen*	Percent of nitrogen retained	
				Dietary	Absorbed
	lb.	gm.		*percent*	*percent*
Basal	.07	-.39	91	8.3	19.2
Urea	.17	1.04	88	9.0	15.4
Urea+SO_4	.18	1.45	93	16.1	26.6
Urea+methionine	.28	2.41	96	22.1	34.5
Linseed meal	.31	2.44	96	21.9	32.9

* Assuming the fecal metabolic nitrogen was 0.55 gm. per 100 gm. of dry matter intake.

methionine increased the rate of gain and the nitrogen retained by the lambs to the same level as was observed on the linseed meal ration. Statistical analyses show that significantly more nitrogen (at the 5 percent level of significance) was stored on the diets containing linseed meal or methionine than on the urea, the urea plus sulfate, or the basal diets. While the true digestibility of the crude protein was slightly higher for the methionine and the linseed rations than for the others this difference was not significant.

Since the addition of methionine to a ration containing urea markedly increased the rate of gain and the nitrogen balance, it appears likely that the protein formed in the rumen by bacterial action was deficient in methionine

or that the diet used was deficient, which in turn may have limited the quantity of protein synthesized. It is clear, however, that under the conditions of this experiment protein arising from urea was much inferior to the protein furnished by linseed meal and that the addition of methionine corrected the deficiency. These results would appear to raise an important question as to the value of urea as a replacement for protein supplements for ruminants in general. Further studies are in progress.

While this test was being completed a report came to our attention (Klose and Fevold, 1944) showing that the protein of yeast is so low in methionine that the growth of rats is adversely affected.

Summary

A study is reported in which protein synthesized from urea in the rumen of lambs is greatly enhanced by the addition of methionine.

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PIT SILOS FOR THE STORAGE OF ATLAS SORGO GRAIN AND OF SOFT CORN[1]

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STORING and utilizing high-moisture grain long has been a problem with corn during certain seasons, and may be encountered even more frequently in the production of sorghum grain. A considerable amount of soft corn can be expected over much of the corn-belt area about once in eight or ten years (Snapp, 1939). In 1917, it was estimated that 43 percent of the corn in the twelve principal producing states was immature at the time of the first killing frost (Rusk and Snapp, 1928). In the case of sorghum grain it frequently is impractical or impossible, even under the most favorable harvesting conditions, to delay combining and threshing until the grain has become dry enough to keep well in storage.

The local prevalence of high-moisture grain at the conclusion of the 1941 growing season, together with an inclination on the part of producers to sell this type of grain for less than its apparent feed value, prompted this study of grain storage in pits. This work was concerned primarily with the influence of pit storage on the composition, general appearance, and palatability of newly threshed sorgo grain and soft corn.

Review of Literature

Grain which contains more than about 13 percent of moisture (Barre and Cotton, 1942) will heat and deteriorate after several weeks or longer in storage, unless these changes are prevented by cold weather or by effective ventilation and drying.

A number of practices have been followed by farmers in attempting to minimize deterioration in high-moisture grains prior to their use in livestock rations. Allowing shocks to stand in the field seems to be somewhat more satisfactory for sorgo grain than for corn, at least to the extent that the latter may freeze too hard in cold weather to be eaten by farm animals (Snapp, 1939). Sorgo grain can be stored temporarily by placing the heads in long narrow ricks from which the grain can be threshed as needed for feeding purposes. The ears of soft corn can be snapped and placed in ricks, in woven-wire enclosures, or in silos (Beeler, 1943). In some areas in recent years, threshed sorghum grain also has been stored in silos constructed by digging pits or trenches (Hall, 1941).

[1] Contribution No. 158, the Department of Dairy Husbandry. Contribution No. 75, the Department of Agricultural Engineering.

Cattle feeding tests with unground hegari grain containing 22 to 31 per cent moisture and stored in trench silos, without or with the addition of water, resulted in smaller gains and a poorer finish than obtained with ground hegari which was cured and stored in sacks before feeding (Jones and associates, 1941). However, the storage of sorghum grain in trenches has been regarded as a successful practice in Texas for several years (Copeland, 1941; Hall, 1941). Milo heads buried in the ground and soaked with water kept well from fall until the following February, when they were found to be palatable feed for dairy cows. But while the resulting grain silage appeared to be good feed, only about 60 per cent of the total grain placed in storage was actually in condition to feed (Hall, 1941). These losses were unexplainable since they failed to show up in the form of spoiled grain. Observations were based on storage in 3 by 3 foot trenches constructed as long as desired and covered with 8 to 10 inches of moist dirt. The investigation indicated that a deep pit might be superior to a shallow trench, and that the storage space should be lined with building paper or other suitable material. Flooding the trenches appeared to result in too much water. Proper ensiling seemed to occur when the grain contained about 30 per cent moisture. Some dry roughage was considered desirable in the ration to control scouring when the grain silage was fed. This investigator also reported that farmers in Texas find that placing cured sorghum grain in trenches more or less protected from rains is effective in controlling insect damage.

Early recommendations (Justice, 1918) stressed the desirability of ensiling soft corn fodder within two weeks after the first killing frost in order to avoid sour, low-grade silage. Ensiling just before frost was considered advantageous in order to preserve more leaves and leaf color (Anonymous, 1924). These, and other reports (Anonymous, 1943; Evvard, 1917); Rusk and Snapp, 1928; Snapp, 1939), indicate that ensiling is one of the best means of storing soft corn.

Dried ear corn was superior to silage made from soft ear corn for swine (Evvard, *et al.*, 1930). Wallace (1927) advocated the evaluation of soft ear corn on a dry matter basis equivalent to not more than 90 percent of the price of dry matter in sound corn. Reports from Illinois (Anonymous, 1924) indicate that soft ear corn stored in a silo compares favorably on a dry basis with normal ear corn. South Dakota workers (Wilson and Bushey, 1926) reported that fattening cattle gained on soft corn at rates comparable to those on mature corn, and recommended using this immature grain as snap corn rather than as husked corn. More recent studies in South Dakota (Johnson, *et al.*, 1943) show that soft ear corn was utilized somewhat better by yearling steers, steer calves, and hogs, than by lambs, and that cattle preferred soft corn to hard ear corn but weight gains were reduced when deterioration of the soft corn was accelerated by warm weather. Rusk and

Snapp (1928) reported that the keeping qualities of ear corn silage are comparable to those of normal silage, and that the feeding value of the dry matter in well-preserved soft corn is equal to that in sound mature corn. Because of its high nutritive value, the storing of immature snap corn as grain silage is suggested as a means of harvesting in favorable weather, and of avoiding the costs of grinding and shelling well-cured corn (Snapp, 1939); hay is recommended in preference to ordinary silage as a source of roughage in rations containing soft corn. Maximum consumption of soft corn is obtained by limiting the roughage intake of cattle to about 4 or 5 pounds daily per 1000 pounds of body weight.

Materials and Methods

Shocked Atlas sorgo and yellow snap corn were purchsaed from local farmers for these studies. The sorgo originated from a crop which yielded 35.5 bushels of grain per acre. Calculations, based on weights obtained after heading and threshing a large portion of this crop, showed that 30 percent of the total weight consisted of heads, and 13 percent of the total weight as purchased was grain. This sorgo had been cut when well matured and before severe lodging had occurred. It stood in shocks for several weeks before it was used in this experiment. In spite of this fact, the newly-threshed grain had a slightly damp feel which indicated that it would have required special handling had it been placed in a tight storage bin at once. Likewise, the stover contained too much moisture for successful stacking as proved by the fact that virtually all of the roughage was spoiled and unfit for feed when the stack was opened several months later.

The snap corn used in this work was in the medium-dough stage of maturity when killed by freezing. It was typical of several local fields of soft corn which was too high in moisture to be marketable through ordinary trade channels.

Using feeds from the above sources, 8 pits were filled between November 28 and December 4, 1941 in the manner indicated in table 1. Each pit was 4 feet in diameter and 5 feet deep, and was lined with one thickness of burlap sacking to reduce soil contamination. The pits were located approximately 4 feet apart in a line extending across a sloping lot in a manner designed to provide as nearly uniform storage conditions as possible for the several feeds (figure 2A). The soil in which these pits were dug was classified[2] as silty clay loam to a depth of three feet, and silt loam in the next two feet of depth. The moisture content in all foot sections of soil examined was at the field moisture holding capacity.

The feed was tramped as thoroughly as possible as each pit was being

[2] Soil samples examined and classified through the courtesy of H. E. Myers, Department of Agronomy, Kansas Agricultural Experiment Station.

filled. When water was used (pits 2, 4, and 6), a hose was directed into each pit part of the time during filling. After filling was completed, water was added in these three pits until it began to run over the lower edge at the top of each pit. A meter was used to measure the volume of water run into each pit. When half-filled with feed, an electrical resistance thermometer was inserted in the feed near the middle of each pit, after which filling was continued until each pit was rounded full. In pits 3 and 4, resistance thermometers also were located four inches and twelve inches from the outer wall at a depth of two and one-half feet in each pit, and a similar thermometer was placed in the middle of each silo six inches beneath the top of the feed. All of these resistance thermometers together with an additional

TABLE 1. DESCRIPTION OF GRAIN STORED IN PIT SILOS

Pit Silo no.	Amount and type of grain, and treatment		
	Lbs. ensiled	Description	Treatment
1	3640	Atlas sorgo, newly threshed	None
2	3260	" " " "	Flooded with water
3	1220	Chopped, unthreshed Atlas sorgo heads[1]	None
4	1460	" " " " "	Flooded with water
5	910	Unchopped, unthreshed Atlas sorgo heads[1]	None
6	1020	" " " " "	Flooded with water
7	1680	Whole, yellow, soft, snap corn[2]	None
8	1760	Chopped[3] " " " "	None

[1] Contained 43% grain.
[2] Contained 33% grain.
[3] Contained 27% grain.

one placed nearby in the ground at a depth of two and one-half feet, were connected with a temperature recording device in a central switch box mounted on a post (figure 2, A). As soon as each pit was filled, one thickness of burlap sacking was placed on top of the feed and this was covered with a mound of soil to a depth of about 10 inches. This soil was wetted with water frequently during the first several days to effect a tighter seal on each silo. The remaining soil, removed from the pits and not used in sealing them, was used to form a ridge along the upper side of the row of pit silos in order to direct surface drainage of water away from the silos.

Each feed was sampled for chemical analysis, germination studies,[3] and other observations. All chemical determinations were made in the Department of Chemistry, Kansas Agricultural Experiment Station.

During the ensiling period, temperature readings were recorded fre-

[3] All germination tests made through courtesy of J. W. Zahnley, Director, State Seed Laboratory.

quently for all resistance thermometers and observations were made on the apparent condition of the seal on each pit.

All pits were opened on August 3, 1942, after about 8 months of storage. Observations were recorded on the kind and extent of spoilage, all spoiled feed was discarded without weighing or sampling, and samples of good feed were taken from each pit for chemical analysis, germination studies, and general observations. Four yearling heifers then were used to study the apparent palatability of the feeds. Ten two-year old heifers were also fed some of these feeds to determine the extent to which the animals would void undigested grain in the feces.

Palatability observations were made over a five-day period by allowing the four yearling heifers to run loose in an exercise lot where they had free access to an ample weighed amount of each kind of feed placed in a separate part of a feed bunk which the animals were accustomed to using. Rations of the feeds were fed twice daily as supplements to good sudan-grass pasture which was available to the heifers for several hours during the middle of each day. For the first three days of this work, the sorgo-head feeds from pits 3, 4, 5, and 6 were placed in the feed bunk first and, after approximately one hour any remaining feed was weighed and discarded. Then weighed amounts of the feeds from pits 1, 2, 7 and 8 were placed in the feed bunk and, after an hour, any amounts which remained were weighed and discarded. The same procedure was followed for each morning and evening feeding during the next two days except that the order of feeding was reversed, so that feeds from pits 1, 2, 7 and 8 were placed in the bunk before those from pits 3, 4, 5 and 6. At the beginning of each hour's feeding, the heifers were forced from one feed to another at first so that each animal would be less apt to eat more of any one kind of feed merely because she chanced upon it first. After each animal had an opportunity to sample each kind of feed, all of the heifers were driven to a distance of several feet away from the feed bunk. Then they were allowed to return and eat undisturbed during the remainder of the hour while observations were recorded on their eating habits.

In the feces-collection studies with the 10 two-year old heifers, only the feeds from pits 3 to 8, inclusive, were fed. Two heifers were fed each of the sorgo feeds, and only one heifer fed each soft corn feed. Facilities were not extended to include the sorgo grain from pits 1 and 2 because other studies (Atkeson and Beck, 1942) indicated that feeding whole Atlas sorgo grain resulted in fecal wastes of 42 percent for grain that was matured and low enough in moisture to store well in a bin, and 11 percent for grain fed in the form of ordinary immature silage. Sufficient, weighed amounts of each feed were fed twice daily over a seven-day period to almost equal the animals' appetites for grain. Any roughage left from the feed of a previous feeding was weighed and discarded just prior to the next feeding. All rations con-

sisted solely of the feed from the pits and water. During the last two days of the seven-day feeding period, all feces voided by each heifer were weighed and sampled for chemical analysis and for grain-recovery studies. Grain was recovered from the feces by weighing out 400 to 500 grams of manure and mixing it thoroughly with two gallons of tap water in a tall glass jar (about 15 inches tall and just large enough to hold the stipulated volume of liquid). After standing undisturbed for approximately one minute, the content of the jar was decanted down to a point where it became difficult to withhold grain particles. The residue was mixed with another jar full of water and again decanted after a brief settling period. This procedure of mixing with water and decanting was repeated an additional eight times whereupon the residue was air-dried for about two or three days. The dried residue then was washed with water about five more times, using the same procedure as described above except that a quart milk bottle or liter beaker was filled to capacity for decanting instead of the two-gallon jar. This second series of washings was helpful in removing residual foreign material. The resulting grain residue which was room-dried and weighed represented the undigested grain recovered from the feces.

In addition to the above investigations at the main experiment station in Manhattan, limited observations also were made with similar-sized storage pits at the Colby and Garden City branches[4] of the Kansas Agricultural Experiment Station. At Colby, approximately 40 bushels of immature Colby milo were placed in an unlined pit and covered with about 12 inches of soil in January, 1942. The grain was removed late in the following August when observations were recorded on the general condition of the feed. At Garden City, four pits were lined with a single thickness of old burlap and filled with a mixture of several different varieties of milo and kafir on January 27, 1942 as follows: (a) 2090 pounds of threshed grain containing 16.1 per cent moisture, (b) 1920 pounds of similar grain wetted with water, (c) 940 pounds of unchopped heads containing 17.8 percent moisture, and (d) 860 pounds of similar heads wetted with water; each pit was sealed with tar roofing paper and 8 inches of soil until the following November 10, when the feeds were removed and their general condition noted.

Results and Discussion

Feed Temperatures

All the feeds became warmer than the ground soon after the pits were filled (figure 1). In pits 2, 3 and 5 these temperatures continued to exceed ground temperatures at the end of the storage period. Temperatures in

[4] Observations at Colby were made with the cooperation of E. H. Coles, superintendent of the Colby Branch Experiment Station, and observations were made at Garden City with the cooperation of L. M. Sloan, superintendent of the Garden City Branch Experiment Station.

these three pits frequently exceeded average daily atmospheric temperatures[5] during the latter part of the storage period. In pit 3, the highest

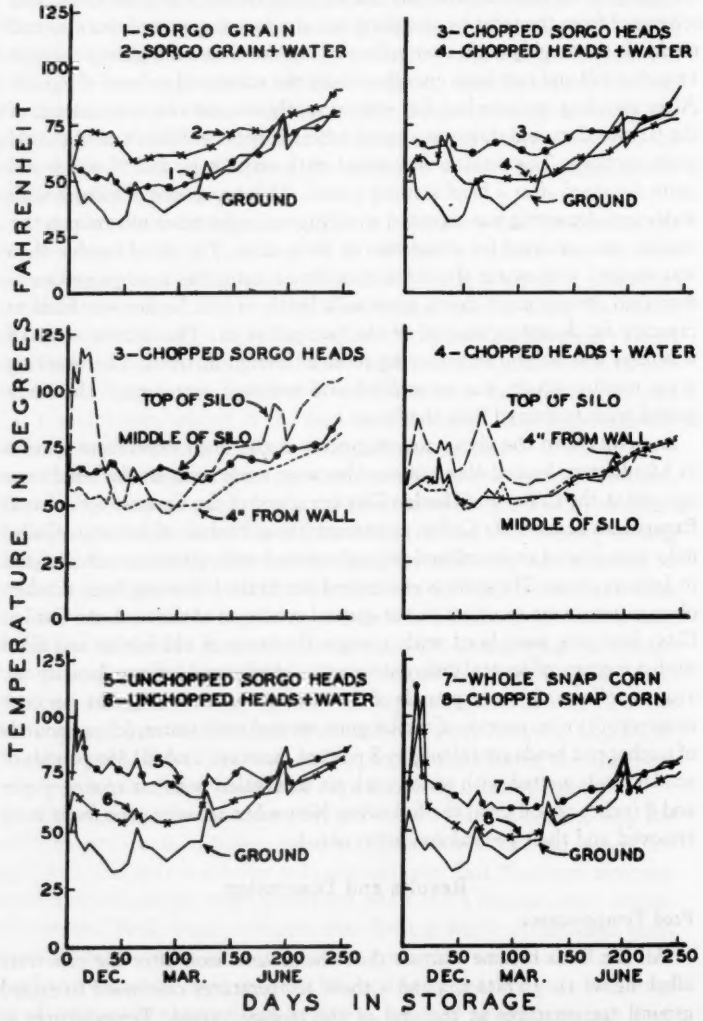


Figure 1. Temperature of feeds in pits, and of ground, recorded during eight-month storage period. All temperature records represent center of silo at mid-depth, unless otherwise indicated.

[5] Based on data obtained from Department of Physics, Kansas State College.

temperature recorded was 106.5°F. versus a maximum atmospheric reading of 102°F.

Ground temperatures reflected changing weather conditions. Winter weather with daily air averages as low as 8°F. was followed, between the 41st and 50th days of the storage period, by daily temperatures averaging as high as 44°F. Ground changes reflected these fluctuations in weather. All temperatures of both soil and feeds increased with warmer weather during the second half of the storage period.

Unsoaked sorgo grain, containing 12.6 percent moisture when placed in storage and 16 percent when taken out (pit 1, table 2), underwent little heating. Similar grain flooded with water contained 29 percent moisture and showed temperatures in excess of those in the ground throughout the eight-month storage interval (pit 2). A total of 55 cubic feet of water was used in flooding this pit, and it had 11 percent less grain capacity than the unflooded pit.

Chopped sorgo heads (pits 3 and 4) heated less and packed better when water was added. Sixty-six cubic feet of water were used to flood pit 4. Similar results were obtained with the unchopped sorgo heads (pits 5 and 6). Eighty-seven cubic feet of water were used to flood pit 6. Chopping increased the pit capacity for sorgo heads by more than one-third in both cases. The flooded, unchopped heads seemed to heat virtually no more than the flooded, chopped heads during storage.

Lower temperatures prevailed in the chopped than in the whole corn. Chopping increased the pit capacity for snap corn by about 5 percent.

In addition to the resistance thermometers at mid-depths in the center of all the pits, thermometers also were inserted at 4 inches and 12 inches from the wall at mid-depth, and in the center at 6 inches beneath the feed surface, in pits 3 and 4. Temperatures 4 inches in from the wall followed ground temperatures rather closely in both pits (figure 1). In pit 3, the temperatures 12 inches in from the wall were about the same as those in the center, and the readings at both of these points were higher than temperatures only 4 inches from the wall. When water was added to the same kind of feed, as in pit 4, the center temperatures at mid-depth were lower than when no water was used (pit 3) but were higher than all the other mid-depth temperatures in this pit; in pit 4, the mid-depth temperatures at 12 inches and at 4 inches from the wall were approximately the same as those in the ground. Readings only 6 inches beneath the surface of the feed in these pits were higher much of the time than those recorded for the mid-depth levels.

General Condition of Feed after Storage in Pits

Eight months after they had been filled, the silos appeared to be well sealed, with no indications of excessive shrinkage of the stored feed.

When pit 1 was opened, the top 2 to 4 inches of sorgo grain was dis-

carded because it was moldy, damp, and spoiled. The next several inches of feed were slightly warm and musty, with a somewhat darkened color. At mid-depth, the grain had retained its original bright color with only a faint musty odor. Nineteen percent of this feed germinated, versus 67 percent when stored 8 months previously. Feeds from all the other pits had zero percent germinations after storage. None of the soft corn samples germinated before or after this feed was placed in the storage pits.

The top grain in pit 2 was light in weight and infested with the flat grain beetle and the rice weevil.[6] The grain was dusty with mold which was extensive to a depth of about 1.5 feet. At mid-depth, the grain was soft and dark-colored, and smelled like silage.

Mold was abundant in the top area of pit 3 and gradually decreased toward mid-depth where the chopped sorgo heads looked like the original material in brightness of color. The grain felt fairly hard as in the freshly stored heads. This feed lacked a typical silage odor.

The soaked chopped sorgo heads in pit 4 were sealed by a 3 to 4 inch cap of rotted, spoiled feed. This came off like a lid. No other spoiled fed was seen in this pit, even next to the wall. The grain was soft and dark-colored, and smelled like silage.

A moderate amount of whitish mold was scattered throughout the first half of the unchopped sorgo heads in pit 5. Some mold was dispersed in the next 2 feet of feed removed, so only a small amount of mold-free heads remained in the bottom of the pit. However, these heads looked as good as the day they were stored. None of this feed smelled like silage.

In pit 7 only a slight amount of top spoilage occurred. However, the husks in the upper foot had a manure-like odor. The remaining feed looked and smelled like good silage.

The chopped, snap corn in pit 8 also had the odor and appearance of good silage. Only 1 to 2 inches of top spoilage was noted in addition to a slight amount of mold next to the silo wall. There was no objectionable odor to the rather dry-like husks such as that noted in the top of pit 7. Except for the top spoilage and the silage odor, the stored feeds in pits 7 and 8 appeared the same as when placed in storage.

The general appearance of each of the stored feeds is illustrated in figure 2, B through I.

This storage test covered a period of rather extreme conditions because of the hot summer weather which not infrequently exceeded 100°F. during the latter part of the storage test. Under usual local conditions, feed supplies of farm-stored grains retained in these forms would have been exhausted

[6] Identified by Prof. George A. Dean, Dept. of Entomology, Kansas Agricultural Experiment Station.

by late spring, which is well in advance of the time when the pits were opened in this experiment.

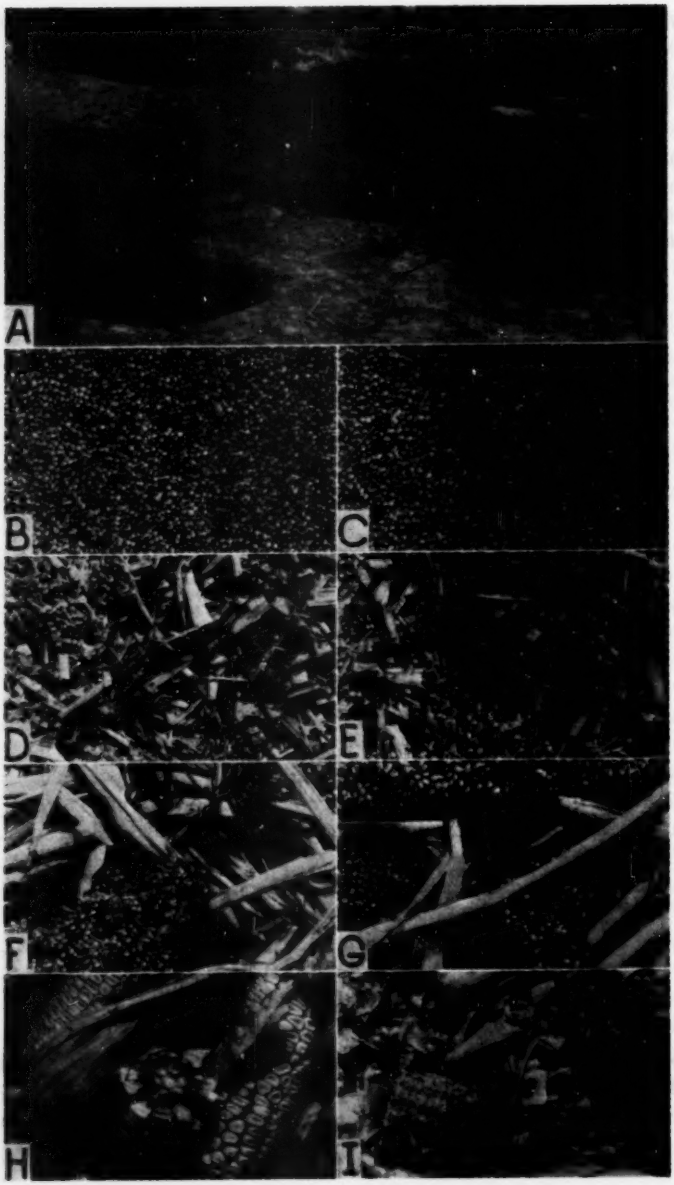
Chemical Composition of Feeds

Moisture percentages increased during storage (table 2). Some of these changes may have been due to water originating from the surrounding soil and from starch being converted into carbon dioxide and water. Although water was run into pits 2, 4 and 6 by flooding, and without attempting to add the same amount of moisture to each pit, it is inetresting to note that the

TABLE 2. CHEMICAL COMPOSITION OF ATLAS SORGO GRAIN AND OF SOFT CORN IMMEDIATELY BEFORE AND AFTER EIGHT MONTHS OF STORAGE IN PIT SILOS

Pit silo		Time of sampling	Moisture	Composition of dry matter								
No.	Contents			Crude protein	Ether extract	Crude fiber	Ash	N-free extract	Sugar		Starch	Carotene
									Total	Reducing		
			per cent	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	*per cent*	Mg./100 gm.
1	Sorgo grain	Before	12.6	12.65	4.06	1.7	2.35	79.2	1.16	0	—	0.14
		After	16.0	12.37	4.25	1.9	2.60	78.9	·0.49	0.45	78.78	0.06
2	Sorgo grain and water	Before	28.6	12.55	4.20	2.1	2.44	78.7	0.90	0.42	—	0.14
		After	29.0	12.59	4.37	1.9	5.94	75.3	0.49	0.45	74.65	0.13
3	Chopped sorgo heads	Before	25.0	10.59	3.27	11.7	5.25	69.2	2.89	2.00	—	0.35
		After	31.7	10.23	3.16	12.4	11.20	63.0	2.42	1.98	55.78	0.20
4	Chopped sorgo heads and water	Before	55.9	9.91	2.99	14.8	6.30	66.0	2.79	2.59	—	0.32
		After	56.2	10.32	3.93	11.9	11.03	62.9	Trace	Trace	49.04	0.21
5	Unchopped sorgo heads	Before	25.3	9.46	2.89	14.6	6.36	66.7	3.28	2.40	—	0.37
		After	25.9	9.88	3.20	14.0	6.26	66.6	0.26	0.22	59.09	0.19
6	Unchopped sorgo heads and water	Before	49.1	10.05	3.04	14.9	5.77	66.2	—	—	—	0.26
		After	55.3	10.09	3.42	15.3	11.34	59.8	1.32	Trace	3.42	0.22
7	Whole snap corn	Before	50.3	9.07	2.94	12.7	3.60	71.7	2.61	2.33	—	0.52
		After	55.0	9.09	3.67	11.8	8.20	67.3	4.71	4.67	59.18	0.82
8	Chopped snap corn	Before	48.8	8.70	2.97	14.7	3.04	70.6	3.14	2.69	—	0.53
		After	57.8	9.72	3.55	11.9	4.24	70.6	1.35	1.28	55.90	0.71

flooded grain in pit 2 had about the same moisture content when opened after storage as did the original fodder when placed in pits 3 and 5. Moreover, flooding the sorgo heads (pits 4 and 6) produced stored feeds with


A
B
C
D
E
F
G
H
I

about the same moisture content as that in the snap corn before and after storage (pits 7 and 8).

Sugar concentrations were lower after storage except for the whole, snap corn in pit 7. These changes as well as those which occurred in nitrogen-free extracts probably were associated with fermentative changes during storage. Less starch was found in the feeds which possessed silage-like characteristics than in comparable feeds stored without flooding. This suggests that some starch was converted either to simpler substances such as carbon dioxide and water or to complex materials such as the gum-like compounds. The formation of such complex substances might help explain why the percentage of nitrogen-free extract sometimes exceeded the sum of the sugar and starch values. Sugar concentrations may have increased in pit 7 through the accumulation of intermediate products formed in the degradation of starch. Inordinately high percentages (17.49 total sugar and 15.29 reducing sugar) were found in a sample of the feed placed in pit 6; for this reason, these data were omitted from table 2.

Carotene concentrations were low in all feeds when placed in storage. The sorgo feeds had somewhat smaller, and the snap corn larger, amounts of carotene after storage. No attempt was made to determine the concentration of beta carotene in each sample.

No special significance is attached to other differences in chemical composition (table 2).

Observations on Feeding Value

All feeds were palatable to yearling heifers, but, when equally accessible in feed bunks, some of the stored feeds seemed to be preferred over others. The animals seemed to show little difference in preference between the chopped and the unchopped sorgo heads from pits 3 and 5. But, even though the flooded feeds (pits 4 and 6) possessed a silage odor, the preference of the heifers for the unflooded feeds from pits 3 and 5 was quite evident. The grain was preferred to the stover in the heads, with the following decreasing order of preference: pits 3, 5, 6 and 4. The sorgo grain from pit 1 was only slightly more palatable than the flooded grain from pit 2. Both of

Figure 2. (A) Arrangement of storage pits and temperature-recording equipment. The four pits in the foreground are ready for lining with burlap prior to being filled. The next two pits are lined with burlap and are ready for filling. The last two pits have been filled and mounded over with soil. (B) Atlas sorgo grain as removed from pit 1. (C) Flooded Atlas sorgo grain as removed from pit 2. (D) Chopped Atlas sorgo heads as removed from pit 3. (E) Flooded, chopped Atlas sorgo heads as removed from pit 4. (F) Whole Atlas sorgo heads as removed from pit 5. (G) Flooded, whole Atlas sorgo heads as removed from pit 6. (H) Whole snap corn as removed from pit 7. (I) Chopped snap corn as removed from pit 8.

these feeds were preferred to those in pits 7 and 8. Even though chopped just before feeding, the snap corn from pit 7 was eaten in smaller amounts than similar feed chopped before storing in pit 8. In spite of these apparent differences in palatability it is probable that anyone of these eight feeds would have been readily consumed if fed alone to hungry animals.

TABLE 3. AVERAGE DAILY FEED CONSUMPTION AND COMPOSITION OF FECES FOR NORMAL DAIRY HEIFERS RESTRICTED TO EXPERIMENTAL STORAGE FEEDS[1]

Heifer		Daily feed intake (lbs.)		Feces		Composition of feces dry matter						Grain in feces[4]
No.	Wt. (lbs.)	Dry matter[2]	Description	Moisture	Gms. d.m.[3]	Crude protein	Ether extract	Crude fiber	Ash	N-free extract	Starch	
				per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
334A	896	14.8	Chopped sorgo	73.1	2462	11.58	2.01	15.7	17.20	53.5	37.38	26
193	1095	12.3	heads									14
195	1203	14.1	Chopped sorgo	72.8	3414	9.23	2.80	16.0	15.93	56.0	44.70	14
192	1118	15.6	heads and water									15
433A	833	15.0	Unchopped	73.9	2078	12.93	2.72	18.4	17.85	48.2	35.64	22
339A	768	14.1	sorgo heads									13
338A	886	16.7	Unchopped sorgo	76.2	3167	11.88	2.94	17.7	18.34	49.1	34.75	9
438A	844	16.3	heads and water									
196	1010	12.0	Whole snap corn	80.3	1967	13.35	2.39	23.4	24.57	36.3	20.51	10
223A	848	11.3	Chopped snap corn	77.8	1649	12.45	2.48	22.2	29.05	33.8	18.54	3

[1] Threshed sorgo grain not fed in this experiment.
[2] Per 1000 lbs. body wt.
[3] Average weight of dry matter voided per animal per day.
[4] Expressed as % of actual grain consumed.

Grain recovery studies of the feces voided by two-year old heifers fed some of the stored feeds are summarized in table 3. There were some indications of less waste of voided grain when flooded sorgo heads were fed instead of unflooded heads. However, the small number of animals used, and the grossness of the grain recovery technique employed, preclude drawing definite conclusions. Analyses of the fecal dry matter showed no obvious trends in composition which appeared to be associated with differences in the percentages of undigested grain in the feces.

Observations at Colby and Garden City Branch Stations

Only 16.5 bushels of the milo were salvaged from the experimental pit at the Colby substation after a storage period of about 7 months. The re-

maining 27.5 bushels was spoiled grain. All the grain in the outer 8 to 10 inches of the storage space, around the wall as well as on the bottom and top of the pit, was either rotten or otherwise spoiled. The grain which was salvaged felt hot when removed from the pit; this grain was fed in hog rations because it was considered unsafe for feeding to dairy cattle.

Observations at the Garden City substation showed that the sorghum grain and the unthreshed heads remained in excellent condition over a period of about 9.5 months, when no water was added to the feeds prior to sealing the pits at the beginning of the storage period. The only evidence of spoilage in these two pits was confined to about the outer 1.5 inches next to the wall of each pit. The stored grain was run through a hammer mill without difficulty. Where water was added at the beginning of the storage period, both heads and grain were found to be in poor condition after storage although both feeds were relished by fattening hogs. The wetted grain had great chunks of moldy feed throughout the mass with only small amounts of grain which were in somewhat better condition. The wetted heads resembled silage and appeared to be in a somewhat better condition than the wetted grain.

Application to Farm Conditions.

These observations show that newly-threshed sorghum grain, unchopped sorghum heads and soft snap corn can be stored in pits without excessive losses, and without added water, for at least several months following the end of the growing season. The failure of immature sorghum grain, of undetermined moisture content, to store satisfactorily in the one pit used at the Colby substation shows that this method of holding feed may be unsuitable under some conditions. However, the reasonably good preservation of some of the feed in each of the remaining experimental pits suggests that this method of storage can be used under many farm conditions. While spoilage was excessive in some of these small experimental pits it was not extensive where mature threshed grain was stored without added water, and it is probable that the percent of such losses as occurred in all the pits can be reduced to much lower percentages by using larger storage pits, and by feeding during the same season.

Summary and Conclusions

Newly-threshed Atlas sorgo grain, and chopped and unchopped heads from the same sorgo crop, were stored separately with and without water in a series of pits. Chopped and unchopped, soft, snap corn also were stored in pits. Each pit was 4 feet in diameter and 5 feet deep. The pits were dug in silty clay loam and silt loam soil which was at its maximum field moisture

holding capacity. Each pit was lined with a single thickness of burlap. These studies at the Kansas Agricultural Experiment Station were supplemented by observations with sorghums in similar pits at the Colby and Garden City substations. The feeds were placed in storage for 8 months, beginning on or about November 28. Chemical analyses were made of samples of feed before and after storage. Temperatures of the feeds and of the soil were recorded during storage. Some observations were made on the feeding value of the resulting concentrates for dairy heifers. Storage periods of 7 and 9.5 months, respectively, were used at the Colby and Garden City substations.

The principal conclusions drawn from these studies are summarized as follows: 1. Sorgo grain, sorgo heads and soft corn can be stored with moderate losses as feed in pits in the ground for periods of at least 8 months after the end of the growing season. 2. Flooding sorgo grain is unnecessary and may be objectionable when using this type of storage. 3. Chopping and flooding with water promoted better packing and less heating of sorgo heads in small pits. 4. Chopping promoted better packing and less heating of soft snap corn in small pits. 5. The proportionately large losses encountered from spoilage in some of the small experimental pits used in these studies probably can be reduced to much lower percentages by using larger storage pits, and by feeding during the same season.

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EVALUATING THE ANIMAL HUSBANDRY STUDENT

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ALL educational institutions must of necessity evaluate their students as regards mentality, but few of them up to the present have developed comprehensive schemes for personality evaluations.

Most teachers probably consider that their task has to do with mind, and that the student or someone else should look out for the proper development of personality. But it seems obvious that in most types of work, a man's success hinges to a greater extent on his personality, his ability to work and to get along with other people than it does on the keenness and training of his mind. There probably are places where brilliant minds coupled with negative personalities can function successfully—some types of research for example—but they are relatively scarce. Fortunately, for most of us, our success depends a great deal more on an acceptable personality than it does upon scintillating cerebration.

Evaluating the Mind

For the evaluation of mind, we commonly use examinations of various sorts—daily, weekly, monthly, final, comprehensive. The success of the examination, of whatever description, will, of course, depend on the objective which the teacher is striving for in his teaching and can be measured only in these terms. If the objective is to "tell students what the facts are and what they mean," then the examinations will consist of finding out how well the students can regurgitate text or lecture material. If we believe that "information is unimportant and that our job is to test the reasoning powers of the students," our examinations and their marking will take on a different hue. If we believe that "the ability to think reflectively and logically is the chief end of the educative process and that thinking implies a store of facts and ideas together with the power of utilizing them in the solution of new and unique problems," the examination will be cast in still another mold.

The traditional type of essay examination has been under heavy attack for the past quarter of a century. To replace it, various types of objective tests have been suggested, true-false, completion, multiple choice, etc. First, we should perhaps admit that neither the old type nor the new is perfect as generally used, nor are they necessarily mutually exclusive. Space does not permit even a brief discussion of all the pros and cons of these methods of testing. All we can do here is to outline some of the more important good and bad features of the essay and the objective types of examination.

Advantages	*Disadvantages*
Essay Type	
1. Can test reasoning, organizing and expository abilities of students.	1. Hard to evaluate fairly and consistently.
2. Gives play to student's ingenuity.	2. Can cover less ground.
3. Student preparation requires discriminating choice of essential facts, principles, relationships.	3. Involves a great deal of time on part of teacher and student.
4. Ability to think necessarily implies a store of facts.	4. Opens way to bluffling and misunderstanding the question so as to write about what he knows.
Objective Type	
1. Easier to score fairly.	1. Teaching held to the lower level of imparting facts—reasoning neglected.
2. Cover more ground.	2. Permits guessing without reason.
3. Save time of teacher and student.	3. Premium on memorizing separate facts.
4. No chance to bluff.	4. Possession of facts does not necessarily imply ability to reason.

It is inevitable that the advantages of one type of examination become the disadvantages of the other, and vice versa. Probably, as in most debatable topics, the truth or the best method lies not wholly in one or the other category. If the process of education consists of treating the minds of students as "storehouses" as well as "workshops," then there would seem to be ample room for the employment of both the objective and the essay types of examination. The fact that the essay type can be used to further the reasoning, organizing, expository and discriminatory powers of students does not, of course, mean that every essay examination will do so. Since the examination bulks so large in our final estimate of the mental stature of our students, it is perhaps safe to say that most teachers could put more time and thought into the formulation, administration and grading of examination papers than has been customary.

Probably the greatest fault of examinations lies in the fact that the questions, quite generally, are artificial. Instead of presenting a realistic situation which would require the student to reach a logical conclusion or solution through the proper use of his store of information and principles, the questions are usually phrased in one of the four D's—Describe, Define, Discuss or Diagram so and so. At this point one is tempted to develop an Examinational Charter of Four Freedoms from the disease (or ease) of the D's. We wonder if some instructors ever come to a realization that it requires about

as much mental exertion on the part of the student in answering questions as the instructor expended in framing them.

Some objectivity at least in grading the papers can be achieved by having the students sign their name at the end of the last question and by the instructor reading the answers to question 1 on all the papers first, then the answers on all the papers to question 2, etc. We are human (hopefully) and therefore easily biased. Not knowing the name of the student whose paper is being graded and doing the grading by the sequence of questions, rather than by the sequence of individual examination papers should minimize bias. It might be advantageous too, if the dean's office could be induced to stop hounding us for grades "within twenty-four hours after the examination period." Evaluating student papers intelligently and fairly is a time (and patience) consuming operation, a fact which most Deans forget when they are advanced to administrative posts (where they will no longer teach) as a reward for good teaching.

Probably one of the best available tools for evaluating the student's mind is the comprehensive examination given toward the close of the student's fourth year in college. For the past several years this has been a regular feature of our program in the School of Agriculture at the Massachusetts State College. Each department in the School of Agriculture sets its own three to six hour written examination for its own majors. In addition, an outside board of three to five agricultural leaders (farmers, county agents, farmers co-op managers, credit specialists, etc.) is brought to the campus and each senior is grilled by this board for a period of 30 minutes. Actually, of course, it is the work of us teachers which is being put on display and there are always some red faces among us as we observe our students floundering about grasping at straws and being led astray through clever questioning. Finally, each senior must prepare and deliver a ten minute paper on a topic of his own choosing and again stand grilling for a like period on the matter he presents, by a different outside board of examiners. These comprehensive examinations force the student to review his work of the four years, to try to draw the loose ends together into a unified whole, and provide the opportunity for all the teachers in the School to get a picture of the effectiveness of their own and their colleagues' work.

Evaluating Personality

When it comes to evaluating the student's personality, we are generally lacking even as inefficient a tool as is the usual recitation or examination as currently used for the evaluation of the student's mind. In fact, some would probably go so far as to say that the subjective qualities of the student are not the concern of the college or the teacher. Most teachers, however,

realize the importance of a well-rounded, attractive personality, but feel that they have no particularly reliable criteria for evaluating such a tricky intangible as personality, and we are "babes in the woods" ar "bulls in China closets" when it comes to suggesting techniques for improvement.

The writer serves in the capacity of freshman adviser. He has fifteen or twenty advisees each year—some intending to major in chemistry, some in liberal arts, some in home economics, or what not; and he is supposed, we presume, to keep them out of the toils of the Dean's office for low marks, or the town jug for low morals, and to see to it that they are started in a field of work which is suitable for their own peculiar talents. Perhaps the most important job is to guide the young person in the adjustment from the sheltered environment of home to the self-expression and self-reliance of the seasoned college student.

We feel that we may be able to be of some help to students in the matter of passing their courses. Any student who can gain entrance to a college can go on to graduation, provided that he knows, or can find out, how to study effectively (and he must soon learn that it is as necessary to study his teachers as his lessons) and provided that he will concentrate on his work for a few hours each day, and provided that he is moderately well-adjusted emotionally. We keep a stack of material on "How to Study" very handy, and it is becoming fairly worn. One student will need sympathy, encouragement and inspiration; another a gentlemanly calling down; while a third may need only a challenge as to his ability to do college work.

Some men come to college with the intention of entering certain fields upon graduation. Sometimes this is the parents' choice; sometimes a random, sometimes a reasoned choice by the students. In too few colleges a is the choice examined in terms of the students' capabilities, and it is true that the scientific approach to career selecting is in its infancy. More men go to college with no definite field of specialization in mind, though often one must be chosen willy-nilly, by the beginning of the junior year. What sort of guidance is available in most colleges? Wouldn't a thoughtful student have a right to expect that the college would provide wise counsel in the choice of his life's work? And shouldn't the college introduce the student to the most interesting thing in the world—himself?

The time is long since passed when every college should start to function in the important field of student guidance. No progressive business institution is without its personnel managers and counsellors, men and women who try to hire round pegs for round holes, and to keep the human mechanism of the whole organization properly oiled, functioning smoothly and developing progressively.

In our opinion every college should have a man or a staff to orient the

freshmen to college life and opportunities, to discover the special abilities of freshmen through the use of mental aptitude tests; to keep a running chart through four years, of the student's mental and personal growth; to discover and suggest means for strengthening the weak spots in the students' personalities; to instruct department heads in proper methods of advising students, and to serve as the Placement Bureau for the college, keeping in touch with occupational trends in all fields for which the college offers training.

When students first appear on our campuses, they are bundles or mixtures of aptitudes and attitudes. The former they have presumably come by largely through the medium of inheritance from their ancestors; the latter has resulted largely from the social milieu in which they have been reared. We need not enter into a futile argument as to which of these is the more important. They are both important, somewhat conditioned each by the other. It is of the utmost concern to the future best interest of the individual that he learn his aptitudes and his attitudes, and that proper strengthening or corrective procedures be instituted as quickly as possible. Need it be argued that this is a job for specialists? How many thousands of students have gone through college getting a smattering of knowledge in a dozen fields or more and remaining in blissful or wishful ignorance of themselves, their own aptitudes and attitudes? Can such an ignoring of fundamentals be expected to result in anything but too many "square pegs in round holes," too many lives lived far below their maximum attainable levels? The most important thing for a student to know is himself—a knowledge more difficult than any other of acquiring by one's self.

To say that the student needs specialized outside assistance in properly evaluating himself does not imply that he is totally unable to help himself. For many years the teaching staff of the Animal Husbandry Department at the Massachusetts State College has been rating students on a short personal rating form. The department head, after averaging the results and after discussion of each student with other members of the teaching staff, has called in each student privately and talked over his rating with him. Judgment and tact are, of course, needed in this procedure; but innumerable comments from graduates in later years have convinced us that the procedure is worthwhile. For the past few years we have had each member of the senior animal husbandry class (usually eight to twelve in number) rate each of the other students. These ratings have also been averaged, and the results for each student communicated to him privately.

Since the procedure seemed worthwhile, we have recently, after enlarging the rating sheet to include twenty-four qualities, begun to use it in the freshman year, thinking it could do no harm to encourage the student to think

FIGURE 1. STUDENT'S PERSONAL RATING FORM

Animal Husbandry Department
Massachusetts State College

Subject's Name Typed Here

Make a check mark on each line at the point which best describes the subject.

1. *General Personality*				
Very likeable	Fairly well liked	Tolerated by others	A prune	
100	75	50	25	0
2. *Honesty—Integrity*				
Completely honest	Generally honest	Fairly honest	A cheater	
100	75	50	25	0
3. *Quality of Mind*				
Very keen	A good mind	Somewhat thick	A dud	
100	75	50	25	0
4. *Acceptance of Responsibility*				
Anxious to accept	Willing to accept	Rather not	A dodger	
100	75	50	25	0
5. *Enthusiasm for Work*				
Full of jiniger	Moderately interested	Just so-so	A dead one	
100	75	50	25	0
6. *Dependability*				
Never fails you	Generally dependable	Not too dependable	A slippery one	
100	75	50	25	0
7. *Thoroughness*				
Painstakingly exact	Fairly thorough	Does it "well enough"	A slacker	
100	75	50	25	0
8. *Sense of Humor*				
Lively	Moderate	Small	A sour puss	
100	75	50	25	0
9. *Moral Posture*				
Erect	Somewhat bent	Stooped	A prone one	
100	75	50	25	0
10. *Initiative*				
Very original	Some originality	An adapter	A copy cat	
100	75	50	25	0
11. *Sense of Proportion*				
Delicate	Normal perspective	Lost in details	Wacky	
100	75	50	25	0
12. *Poise and Self-Confidence*				
Pleasingly cocky	Self-reliant	Uncertain	A skeered one	
100	75	50	25	0

FIGURE 1, *continued*

13. *Ambition*				
A go-getter	He'll get there	Not much evidence	A lazy one	
100	75	50	25	0
14. *How Does He See Life*				
In high good humor	Matter of fact	Rather seriously	A long face	
100	75	50	25	0
15. *Cooperativeness*				
Out of his way to help	Fairly obliging	Will if he has to	An off ox	
100	75	50	25	0
16. *Leadership*				
A General	1st Looie	Top-Sgt	A buck private	
100	75	50	25	0
17. *Tact*				
A diplomat	No offense	Gets along lamely	Bull in china closet	
100	75	50	25	0
18. *General Appearance*				
Neat-in good taste	Presentable	Untidy	A tramp	
100	75	50	25	0
19. *Habits of Work*				
Orderly and untiring	Good worker	Works in circles	A fritterer	
100	75	50	25	0
20. *Imagination*				
Like a poet	Considerable	Prosaic	A "sanka"	
100	75	50	25	0
21. *Tolerance and Liberality*				
Very broad gaged	Fairly liberal	Rather narrow	A puritan	
100	75	50	25	0
22. *Ability to Express Himself*				
With ease and force	A bit labored	Rather hesitant	Tongue-tied	
100	75	50	25	0
23. *Perseverance*				
A bulldog	Keeps swinging	Sour grapes	A quitter	
100	75	50	25	0
24. *Aptitude for Animal Husbandry*				
Exceptionally high	Average	Not too much	A sissy pants	
100	75	50	25	0

Animal Husbandry Department
Massachusetts State College

Subject's Name Typed Here

about himself as a personality somewhat earlier than in the last two weeks of his senior year. The rating form now in use is presented in figure 1. The directions for each of the four years are as follows:

For Freshman Students in Animal Husbandry

Your are now embarking on a four-year college program. You alone know what kind of a crop you expect to harvest during these next four years. Your instructors are here to help you in every possible way, and some of us will probably make the serious mistake of doing things for you which you could and should do for yourselves.

You will grow physically during your stay on this campus.

You should also grow in character, mental acumen, and the fine art of discrimination.

To help you chart your progress, you are now asked to score yourself on the attached sheet. This is for your information and for you to keep, we will not collect them.

But we do ask you to make out a duplicate sheet and place it in an envelope which you will seal. We will collect these sealed envelopes and put all of them in a large envelope which will be sealed. We shall ask you to fill out another such sheet next year at the opening of college, and when you have done so, we will open the envelope containing this year's envelopes and let you compare this year's rating with the one you will have made out next year. The process will be repeated at the beginning of your junior and at the close of your senior years also in order that you may have a chart of your development.

No one but yourself will ever see your sheet unless you choose to show it. If you leave college for any reason, your envelope either will be mailed to you or destroyed without opening. You are invited to come in and talk over your own rating of yourself with any member of the Animal Husbandry teaching staff anytime you wish to.

For Sophomore Students in Animal Husbandry

Perhaps you remember that one year ago, when you were a very green freshman, you filled out a rating scale on yourself and we sealed it and tucked it away in the safe. Now you are a sophomore—characterized by President Woodrow Wilson as a "person in whom the sap of manhood has started to rise—but it has not yet reached his head."

We now ask you to rate yourself again, making two copies, one of which you may keep. We will then give you your own envelppe from last year, which you may open so as to compare this year's rating with last year's. You will then place both last year's and this year's rating sheet in an envelope and seal it; and we will again collect the envelopes—put them into a large envelope and let them gather dust for a year.

For Junior Students in Animal Husbandry

Another year has flown, and you are now ready to begin your serious work in your chosen field. How is your growth in mental acumen and character proceeding? During the past two years have you shed more bad habits than you have acquired?

You remember the self-rating sheets you filled out at the beginning of each of your first two years in college. Here they are, still sealed as you left them a year ago, and they are now yours. But before we given them to you, fill out the sheet once more so that you can evaluate your progress during the past two years.

For Senior Students in Animal Husbandry

You will soon leave these cloistered halls to go into a world which will quickly size you up and label you. How will you rate? What sort of life lies just ahead for you? How will you adjust to real life?

Your fellow students and your instructors have lived intimately with you for four years. It would seem silly to let you go your way without the benefit of our combined judgment concerning you. Every individual is a mixture of good and bad qualities, and as individuals we hesitate to tell our friends their faults. But if we never discover our weak spots, how are we ever going to strengthen them?

Each student will first rate himself and retain his own rating sheet. Then each student will rate each of his classmates and the members of the Animal Husbandry teaching staff will

also rate each student. These sheets will be collected and the averages of all the ratings for each student (except his personal rating) will then be tabulated, and each of you will be given your own average rating to compare with your rating of yourself. Naturally, all of this material will be strictly confidential, and the Head of the Animal Husbandry Department will talk over the results of your rating with you privately.

You are not sitting in judgment on your fellow students.

You are helping one another to discover the weaker points in your armor.

You are going to rate each of the other students in this class, so work carefully in your placing and "don't break type."

Be honest—be frank—do not be soft nor over-critical. Do not sign your name nor make any other identifying mark on the rating sheets.

The purpose in using these personal rating forms is two-fold: (1) to begin early to call the student's attention to the fact that he is a personality; to get him to thinking about himself as a person; to give him a scale by which he can measure himself; to suggest that his own personality is perhaps his most valuable possession and that it can be strengthened and improved if he has the will to tackle the job; and (2) to give him, finally, an insight, in an impersonal way, as to how his personality rates with his fellow students and his instructors after they have lived with him for four years.

The trouble with this and any other rating scales lies in the fact that they are inventories of parts with the relationship between the parts left entirely out of consideration. Students, after all, are persons—not just bundles of traits. In commenting on this point, F. Alexander Magoun of M.I.T. wrote the author as follows:

The sum of the parts of a watch is a very different matter from their right relationship. Reliability, for example, is in terms of the relationship between physical capacities, emotional control, comprehension, ability to give or to get cooperation, etc. Some day we may have a Watt meter for these things. Now we are only seeing them superficially. Why is Joe uncooperative or sullen or careless or dishonest is the important thing. That he is so may only be a symptom of something wrong in the way he is being handled.

Evaluating implies standards of measurement or comparison provided by the college and the teacher. Whether we are presently devoting as much attention to the matter as its importance justifies, may be open to question. We are not overly sanguine as to our ability to revamp personalities—although the matter of developing mental acumen and keener powers of discrimination we generally proclaim as our rightful prerogative. The student, we feel, can rightfully expect the type of training which will quicken his mental faculties. But we know that his success will depend as much, if not more, upon his personality traits—especially on how successfully he can make adjustments and get along with people. It would, therefore, seem to be both our duty and our privilege to evaluate the student both in terms of mentality and personality, not once but many times, and beginning when he is a freshman. When graduation arrives, we should have a chart of each, man over the previous four years. While not necessarily overoptimistic

it would seem that, if we get a line on the qualities, good and bad, of each student while he is a freshman, the proper procedure could be developed so that each student could at least be made cognizant of his weaker points and tactfully offered suggestions as to how bad habits might be supplanted with those of a somewhat better sort.

NEWS AND NOTES

An announcement in the August issue indicated that the Executive Committee of the American Society of Animal Production had decided to cancel the annual meeting for 1945. Owing to the end of the war, the question of holding a meeting again arose. An O.D.T. limit of 150 persons attending conferences is still in effect, and the travel and hotel situation is still unsatisfactory, hence the Executive Committee has reaffirmed its earlier decision, and no meeting will be held this year.

The Nominating Committee, consisting of George A. Brown (Chairman), R. M. Bethke and G. H. Hart, recommended that the present officers of the American Society of Animal Production serve again during 1946, or until an annual meeting is held and their successors duly elected. The Committee also stated that if the Executive Committee felt that it was necessary to hold an election by mail, the Nominating Committee wished to nominate the present officers to succeed themselves. In view of these recommendations, the Executive Committee felt that an election by mail would be superfluous and approved the recommendation that the present officers continue in office during 1946.

B. T. Simms, director of the U. S. Regional Animal Disease Research Laboratory, Auburn, Alabama, will become Chief of the Bureau of Animal Industry, succeeding A. W. Miller, who retired on October 31.

Samuel Brody of the University of Missouri is the author of a book entitled "Bioenergetics and Growth," which was published in August by the Reinhold Publishing Corporation, 330 West 42nd Street, New York, N. Y. The volume contains 1,023 pages and the price is $8.50. This book contains a compilation of the results of extensive research work conducted by Dr. Brody, or under his supervision, and these results are integrated with related findings of other workers. There are twenty-four chapters which deal comprehensively with various phases of bioenergetics and growth. Attention is given to both the fundamental principles and to their application in livestock and poultry production. It is impossible to give any real indication of the contents in a brief paragraph, for, in the words of an introductory quotation, "The situation is complicated and its difficulties are enhanced by the impossibility of saying everything at once." In the 25th and final chapter the author summarizes and integrates the various phases discussed in earlier chapters. This will be an invaluable reference book for all animal husbandry workers and students who deal with problems of growth, energy metabolism and efficiency of animals.

Fred F. McKenzie, professor of animal husbandry at Oregon State College, left for Chile in October to spend a month there assisting the government in the setting up of an artificial insemination program.

E. J. Iddings, dean and director of the College of Agriculture, Experiment Station and Extension Service at the University of Idaho since 1913, retired on November 1. C. W. Hickman, head of the animal husbandry department, became acting dean and director at that time.

Joseph Edwards, formerly with Dr. John Hammond at Cambridge University, became head of the newly created department of dairy husbandry in the British Milk Marketing Board at Thames Ditton, Surrey, England on July 1, 1945. He is responsible for operation of the National Milk Records, the national plan for the development of artificial insemination in England and Wales, and statistical studies of milk records.

G. S. Fraps retired on August 31 from administrative work as State Chemist and Chief of the Division of Chemistry of the Texas Agricultural Experiment Station, but will remain with the Experiment Station on a part-time basis, with the title of Collaborating Chemist.

Victor R. Berliner, formerly of the Mississippi State College is now with the Lucas Farms in Fowlerville, Michigan. This farm maintains a large number of horses that are used for production of mare urine for Parke, Davis and Company, and Dr. Berliner is working on breeding and chemical phases of their operations.

T. Y. Hsu of the Chinese Ministry of Agriculture, who visited many institutions in this country during the winter of 1944–45, under the auspices of the United Nations Relief and Rehabilitation Administration's program of training for reconstruction work, departed for China in late May, and reached his native country in July. During 1943, Mr. Hsu served as official guide and interpreter for Ralph W. Phillips while he was traveling in China under the auspices of the U. S. Department of State.

Phillip L. Kelly, formerly of the University of Arkansas, recently resigned from his position at that institution to become head of the department of dairy husbandry at South Dakota State College.

E. A. Warner, extension animal husbandman, Oklahoma A. & M. College, recently resigned to become livestock specialist with the Chicago Flexible Shaft Company and was succeeded by Fred W. Ahrberg, county agent in Osage County, Oklahoma.

Cecil W. Creel of the University of Nevada is now dean of the College of Agriculture as well as director of extension.

Jerry Sotola, formerly of the animal husbandry staff at Washington State College and lately with a commercial concern, was recently made associate director of Armour's Livestock Bureau, Chicago.

Wilbur J. Fraser, of the University of Illinois dairy department, died April 18, 1945, after a prolonged illness, at the age of 76 years.

John O. Williams, for more than 35 years with the U. S. Bureau of Animal Industry and most recently superintendent of the U. S. Morgan Horse Farm, Middlebury, Vermont, voluntarily retired on August 15 and has been succeeded by Earl B. Krantz. Mr. Williams is now with the United Nations Relief and Rehabilitation Administration in Washington.

J. L. Krider has succeeded B. W. Fairbanks, resigned, as chief in swine husbandry at the University of Illinois.

E. W. Janike, former assistant animal husbandry specialist, University of Nebraska, is now secretary of the Omaha Live Stock Exchange.

M. L. Buchanan, associate professor of animal husbandry at North Dakota State College was made secretary of the Columbia Sheep Breeders' Association at recent annual meeting. W. A. Denecke, formerly of the U. S. Sheep Experiment Station, Dubois, Idaho, was relected president of the organization.

J. A. Beall of the Oklahoma A. & M. college animal husbandry staff recently resigned to devote his time to horse breeding and other personal interests at Nash, Oklahoma.

Harold R. Lascelles was appointed professor of animal husbandry at Colorado State College, effective October 1, in charge of resident instruction and research in dairying, replacing Howard C. Dickey, who joined the staff at the University of Vermont.

E. J. Maynard, formerly in the animal husbandry departments at New Mexico, Colorado and Utah is now general livestock consultant for the Great Western Sugar Company with headquarters in Denver, Colorado.

A. T. Semple, formerly of the staffs of the Bureau of Animal Industry and Soil Conservation Service, United States Department of Agriculture, and more recently in Africa on assignment for the Foreign Economic Administration, has gone to South America, where he will have charge of an experiment station in Bolivia for the Office of Foreign Agricultural Relations, United States Department of Agriculture.

F. B. Morrison has relinquished administrative responsibilities at Cornell University, and has been succeeded by K. L. Turk as head of the department. Dr. Morrison will remain a member of the staff.

B. M. Anderson, secretary of the American Hereford Association, and formerly member of the animal husbandry staff, Kansas State College, died on October 4, 1945.

H. H. Kildee will become director of extension work at Iowa State College, July 1, 1946, on the retirement of R. K. Bliss, present director, and will also retain the deanship of the agricultural division, which he has held for several years.

W: M. Beeson, formerly of the animal husbandry staff, University of Idaho, now has charge of animal nutrition work at Purdue University.

J. R. Hutcheson, first extension animal husbandman at Virginia Polytechnic Institute, and later director of extension, was recently elevated to the presidency of the same institution.

Charles S. Hobbs, recently extension animal husbandman, Cornell University, has been made head of the animal husbandry department, South Dakota State College.

C. L. Cole, of the animal husbandry staff, Michigan State College, recently resigned to take a position with the Willys-Overland Company.

A. O. Shaw, former head of animal husbandry at North Carolina State College, and more recently in private employment, has been made head of animal husbandry at the University of Maine.

C. M. Kincaid recently returned to Virginia Polytechnic Institute after receiving the degree of doctor of philosophy at Iowa State College.

George R. Johnson of the Cornell University extension staff, is now taking graduate work at Michigan State College.

Paul E. Howe, who has been with the War Department in nutrition work overseas, is now on terminal leave in preparation for return to divilian duties.

The staff of the Animal and Poultry Husbandry Branch of Army Educational Center No. 12 at Shrivenham, England, was reported as follows at the beginning of the training period: A. E. Darlow, Oklahoma A. & M. College; Ralph B. Cathcart, Kansas State College; Henry G. Sellards, University of Kentucky; Earl Weaver, Michigan State College.

R. R. Snapp, formerly of the University of Illinois animal husbandry staff, is now teaching animal husbandry in the Army Educational Center at Florence, Italy.

"Shepherds Empire" is the title of a new 364-page book by Chas. W. Towne and Edward N. Wentworth, published by University of Oklahoma Press. It is a history of sheep in North America with many side lights.

Wade G. Wells has been appointed assistant extension animal husbandman at the University of Idaho, with headquarters at Boise.

H. A. Stewart, formerly assistant professor of animal husbandry at the University of Minnesota, is now associate in animal genetics research at the North Carolina State College in Raleigh.

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